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A
COURSE of LECTURES
IN
NATURAL and EXPERIMENTAL
PHILOSOPHY,
GEOGRAPHY *and* ASTRONOMY:

IN WHICH THE
PROPERTIES, AFFECTIONS, and PHÆNOMENA
of NATURAL BODIES, hitherto diſcover'd,
Are exhibited and explain'd on the
Principles of the *NEWTONIAN* PHILOSOPHY,
Under the following HEADS, *viz.*

PHYSICS; or the Doctrine of MATTER, and its eſſential PROPERTIES.
MECHANICS; or the Doctrine of MOTION, and all Kinds of *Forces* and *Machines.*
HYDROSTATICS; or the Nature and Laws of FLUIDS explained.
HYDRAULICS; or the Theory of the MOTION of *Fluids*, and of all Kinds of *Water-Engines.*
PNEUMATICS; or the Nature and various Properties of the AIR and ATMOSPHERE.
PHONICS; or the Theory of the WINDS, SOUNDS, *Muſical* STRINGS, NOTES, *&c.*
LIGHT and COLOURS explain'd, according to the NEWTONIAN *Theory.*
OPTICS; or the Science of VISION, and THEORY of all Kinds of *Optical Glaſſes* and *Inſtruments.*
ASTRONOMY; or the SOLAR SYSTEM of the *Planets* and *Comets*, and Uſe of the *Celeſtial Globe*, explain'd.
GEOGRAPHY; or the *Theory* of the EARTH, and Uſe of the *Terreſtrial Globe*, explain'd.

The Whole confirmed by EXPERIMENTS, *and illuſtrated with* COPPER-PLATES.

To which is added,
An APPENDIX, explaining all the CHARACTERS, PHRASES, and difficult WORDS, which occur in theſe LECTURES, and other Treatiſes of this Kind.

By *BENJAMIN MARTIN.*

> *Quæ toties animos veterum torſêre Sophorum,*
> *Quæque Scholas fruſtra rauco certamine vexant,*
> *Obvia conſpicimus, nubem pellente Matheſi.*
>
> HALLEY in NEWTONI Princip.

READING,
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BRITISH MUSEUM
27 OCT 53

TO THE MOST

CONSPICUOUS and ILLUSTRIOUS YOUTH,

THE

Earl of MARCH,

ELDEST SON of the

Duke and Ducheſs of *RICHMOND*,

THIS

COURSE of LECTURES

IN

Natural and *Experimental* PHILOSOPHY

Is moſt humbly ADDRESSED and INSCRIBED

By His LORDSHIP's

Moſt Obedient and

Moſt Devoted Humble Servant,

BENJAMIN MARTIN.

BRITISH MUSEUM
27 OCT 53

PREFACE.

THE *Reaſon of my printing theſe* LECTURES *is, that they might be in the Hands of my Subſcribers, to peruſe not only while they attend my Lectures, but after the Courſe is finiſhed, to retain and fix thoſe fleeting Ideas which they acquire from a tranſient View of ſuch a Multiplicity of Subjects and Experiments. And, indeed, it is by this means only that a* Courſe of Experimental Philoſophy *can be made of any ſubſtantial and laſting Uſe to the Subſcribers; who otherwiſe muſt find it prove little more than a ſublime and rational Amuſement, for the inſtant Hours.*

My ſecondary View was, once more to ſerve the Publick, by preſenting them with a Courſe of Lectures in Natural and Experimental Philoſophy compleat, ſo as to form a general Idea or Plan of the Science; *which, it is hoped, will be ſo much the more acceptable, as it contains an Account and Deſcription of many new Inſtruments and Experiments, and ſeveral great Points of the Science explain'd, which are no where elſe to be found in a* Courſe of Lectures.

Again; another thing, which I had a principal View to, was my Character or Reputation as an Illuſtrator of Experimental Philoſophy; which I thought myſelf the more obliged to have regard to, inaſmuch as there are many ignorant *and* empirical Pretenders *gone out, who obtrude themſelves and a ſpurious* Apparatus *on the good-natur'd and generous Part of Mankind, who are not apt to ſuſpect or think ill of a Perſon, till (too late they find) they have been decoy'd and deceiv'd by him; and then they are prejudiced againſt and reject all Propoſals of this Kind for ever after. Thus is the noble Science brought into Contempt and Diſrepute, by the Ignorance and Effrontery of a Set of Men, whom either the* Res anguſta domi, *or the* Auri ſacra fames, *will compel to undertake any thing.*

In the laſt place, it was not the leaſt Part of my Deſign, to render this Courſe of Lectures plain and eaſy to be underſtood by all Capacities in general, and in particular by the Fair Sex: *For why ſhould not the* LADIES *underſtand and ſtudy the Sciences of* Humanity, *of which* PHILOSOPHY *holds the* Firſt Place? *Knowledge is now become a faſhionable Thing, and* Philoſophy *is the Science* a la Mode: *Hence, to cultivate this Study, is only to be in Taſte, and* Politeneſs *is an inſeparable Conſequence. Wherefore nothing can be more conſiſtent and rational, than that the Ladies ſhould ſtudy* Philoſophy; *or more monſtrous and ſtupid, than that Objection which is ſometimes made againſt it, viz.* That the Gentlemen will not like them ſo well for it. *This is a groſs Reflection on the good Senſe of Gentlemen, and tends to deprive the Ladies of thoſe Qualities which would principally recommend them to their valuable Eſteem and Choice.*

Nothing can be more ſhocking than to hear ſome Men vilify this Noble Science by aſking, Of what Uſe is Philoſophy? What ſhall we get by it? What ſhall we be the better for it? *and ſuch-like derogatory and abſurd Queries. If they think, as they are ſometimes pleaſed to ſay,* That Philoſophy is a Thing out of their Way, *it would much become them not to pretend to Humanity, or any Degree of Rationality, which muſt be extremely abſurd and ridiculous; and I ſhall take the Liberty to make them a particular*

Claſs or Species of Beings, under the Title of Hominiform Animals, *or a Species* ſui Generis.

But, without deſigning a Panegyric on Philoſophy, I will venture to aſſert, that there is no Art, Profeſſion, *or* Buſineſs *of Life, wherein an intelligent Artiſt will not find the greateſt Service and moſt beneficent Effects redound from this Science. Does not every one know, that* RELIGION *is founded wholly in* Philoſophy, *or a* true Knowledge of Nature? *Is it not from thence that we have the firſt and trueſt Notions of the Divine and Adorable* CREATOR *of all Things, and the moſt direct and cogent Arguments for his* Exiſtence *and* Perfections? *In ſhort, 'tis a Contradiction to call any Man a* Divine *or* Theologiſt, *who is not a* good Philoſopher.

Again; *in regard of* CHEMISTRY, PHARMACY, *and* MEDICINE, *no Man of common Modeſty can pretend to the leaſt Merit, Character, or Judgment in theſe Arts, who does not underſtand the Power and Agency of the corpuſcular Parts of Matter, and the different Effects ariſing from the various Mixtures and Aſſociations of the original Particles of Matter in heterogeneous Bodies*; *the various* Hydroſtatic *and* Hydraulic *Laws of Fluids*; *the Parts and Structure of an Animal Body*; *the Animal Oeconomy, and the Influences of the* Sun *and* Moon *upon it: The Principles of which are no where to be found, but in the ſeveral Branches of this Science.*

As to OPTICIANS, *the Theory of their Art wholly depends on* Philoſophy, *or rather, it makes the moſt delightful Part of the Science itſelf. No Man therefore muſt pretend to underſtand the Nature, Structure, or Effects of a* Microſcope, *a* Teleſcope, *or a Pair of common* Spectacles, *yea, nor even the Nature and Uſe of his own* Eyes, *who has not made ſome conſiderable Progreſs in the Study of* Philoſophy.

PREFACE.

In NAVIGATION, SURVEYING, DIALLING, *&c. who knows not the Uſe of the Loadſtone, and the Magnetical Needle? And how aukward muſt an Artiſt of this Sort appear, who is acquainted with no other Property of this wonderful Body, but that which makes his Needle point* Northwards?

In GUNNERY, *the* Engineer *finds the whole Theory of his Art founded in* Philoſophy, *viz. in the* Doctrine of Projectiles, *and the* Motion of heavy Bodies *falling freely by the Power of Gravity. From hence alone he can diſcover that the Path of the Bomb is a* Parabola, *and what relates to the Impetus, Elevation, Time, and Random of the Shot or Projection.*

ASTRONOMY *owes all its Principles to Obſervation and Experiments, and conſequently to* Philoſophy. *The general Law, which all the Heavenly Bodies obſerve, is conformable to the Laws of Gravity, or the Doctrine of* Central Forces, *as I have ſhewn in its Place. But why ſhould I mention Particulars, when the whole Science makes but a particular Branch of* Philoſophy?

GEOGRAPHY *is employ'd wholly in philoſophical Speculations, relating to the* Form *or* Figure, *the* Magnitude, *the* Motions, *or* Gravity *of the Earth*; *the* Variations *and* Viciſſitudes *of the* Seaſons; *the Diviſion of the Surface into* Land *and* Water: *And many other Affections of Moment can only be well underſtood from a philoſophical Account thereof.*

Even POETRY *borrows from this Science thoſe Ideas, Deſcriptions, and Subjects, which moſt of all ennoble it, and make it appear inſpired and ſublime. Hence all our great Poets conſtantly invoke the* Philoſophic Muſe, *(the* Dulces Muſæ *of* Virgil) *witneſs* Heſiod *and* Homer, Virgil *and* Ovid, Milton *and* Pope; *whoſe*

Names and Poems nothing can more contribute to eternize, than thoſe fine and lofty Reflections and Strictures of Natural Science, which diſtinguiſh their Works from the Productions of inferior Genii.

But what needs Prolixity? Is not all MECHANICS, *and every Mechanic Art or Trade, founded in* Philoſophy? *Can any Man account for the Effects of the* Hammer, *the* Chiſel, *the* Sciſſars, *(thoſe vulgar Machines) not to mention the* Lever, *the* Pulley, *the* Screw, *&c. without ſome Degree of* Philoſophy? *I affirm he cannot; and further, that thoſe who learn the practical Part, without knowing any thing of the Theory or Reaſon of what they do, are to be conſider'd in the ſame View with the loquacious* Parrot, *and mimic* Chimpanzee, *rather than human or rational Artiſts: For it muſt be with the utmoſt Impropriety that we call thoſe Creatures* rational, *who* underſtand not the Reaſon of Things in general.

And to the End that no Objection may lie againſt the Study of ſo valuable and uſeful a Science, I have added an Appendix, *giving an Explication of all difficult Words, Terms, and Characters, which are uſed and do often occur, not only in the Courſe of theſe* Lectures, *but in all other Books of modern Date, on this Subject. Alſo a compleat* Index *is ſubjoined, referring to the Pages where every Word or important Point is explain'd.*

In the laſt place, Gentlemen will here find a Deſcription and Prints of ſeveral new Philoſophical Inſtruments *and* Experiments *no where elſe to be met with. The Experiments are all number'd or regiſter'd in the Margin, the better to aſſiſt the Memory, and to avoid Confuſion: And, in ſhort, I have omitted nothing that I know of, which could be done, to make every thing as eaſy and intelligible as the Nature of the Subject, and the Limits of the Work, would admit.*

To conclude, I ſuppoſe no Perſon has ſo ſmall a Share of Senſe, as to imagine, that becauſe we have attempted to aſſign the Reaſon of many Things, we do therefore pretend to account for all the Phænomena *of Nature: Or, on the other hand, becauſe all Things are not to be underſtood, we are therefore not concern'd to account for any. 'Tis certainly every Man's natural Duty to learn and teach as much as he can of the wonderful Works and ſurprizing Operations of Nature; and to admire the reſt, and adore their infinitely wiſe and powerful* CREATOR; *according to the Poet,*

—— Nam Rerum Parens,
Libanda tantum quæ venit mortalibus,
Nos ſcire pauca, multa mirari jubet.

LECTURE I.

THE Buſineſs of Experimental Philoſophy, (the Subject of this Courſe of Lectures,) is to enquire into and inveſtigate the Reaſon and Cauſes of the various Appearances (or *Phænomena)* of Nature; and to make the Truth or Probability thereof obvious and evident to the Senſes, by *plain, undeniable, and adequate Experiments*, repreſenting the ſeveral Parts of the grand Machinery and Agency of Nature.

IN our Enquiries into Nature we are to be conducted by thoſe Rules and Maxims which are found to be genuine, and conſonant to a juſt Method of Phyſical Reaſoning; and theſe Rules of Philoſophizing are, by the greateſt Maſter in this Science, (the incomparable Sir *Iſaac Newton*,) reckon'd Four; which I ſhall give, from his *Principia*, as follows:

RULE I. *More Cauſes of natural Things are not to be admitted, than are both true and ſufficient to explain the Phænomena.* For Nature does nothing in vain, but is ſimple, and delights not in ſuperfluous Cauſes of Things.

RULE II. *And therefore of natural Effects of the ſame Kind, the ſame Cauſes are to be aſſign'd, as far as it can be done.* As of Reſpiration in Man and Beaſts: Of the Deſcent of Stones in *Europe* and *America:* Of Light in a culinary Fire and in the Sun: And of the Reflection of Light in the Earth and in the Planets.

RULE III. *The Qualities of natural Bodies which cannot be increaſed or diminiſh'd, and agree to all Bodies in which Experiments can be made, are to be reckon'd as the Qualities of all Bodies whatſoever.* Thus becauſe Extenſion, Diviſibility, Hardneſs, Impenetrability, Mobility, the *Vis Inertiæ*, and Gravity, are found in all Bodies which fall under our Cognizance or Inſpection, we may juſtly conclude they belong to all Bodies whatſoever; and are therefore to be eſteemed the original and univerſal Properties of all natural Bodies.

RULE IV. *In Experimental Philoſophy, Propoſitions collected from the Phænomena by Induction, are to be deem'd (notwithſtanding contrary Hypotheſes) either exactly or very nearly true, till other Phænomena occur by which they may be render'd either more accurate, or liable to Exception.* This ought to be done, leſt Arguments of Induction ſhould be deſtroy'd by Hypotheſes.

IF according to theſe Rules we take a Survey of the viſible World, and ſtrictly examine the Nature of particular Bodies, we ſhall find that they all conſiſt of *one and the ſame Sort of Matter or Subſtance*; and that all the Diverſity or Difference we obſerve among them ariſes only from the various Modifications and different Connection or Adheſion of the ſame primigenial Particles of Matter.

MATTER, thus variouſly modified and configurated, conſtitutes an infinite Variety of Bodies, all which are found to have the following *common Properties*, viz.

EXTENSION, or that by which it poſſeſſes or takes up ſome Part of univerſal Space; which Space is call'd the PLACE of that Body. For all Bodies are *extended* either (1.) into *Length* only, and then it is called a LINE; or (2.) into *Length* and *Breadth*, which is call'd a SUPERFICIES; or (3.) into *Length*, *Breadth*, and *Depth*, which then is call'd a SOLID. Theſe are the *three Dimenſions*, according to the Quantity of which the *Magnitude* or Bulks of Bodies are eſtimated.

SOLIDITY, ſometimes called the IMPENETRABILITY of Matter, is that Property by which a Body excludes all others from the Place which itſelf poſſeſſeth; for it would be abſurd to ſuppoſe two Bodies could poſſeſs one and the ſame Place at the ſame Time. From this Definition it follows, that the *ſofteſt Bodies* are equally *ſolid* with the *hardeſt*.

DIVISIBILITY is that Property by which the Particles of Matter in all Bodies are capable of a Separation or Diſunion from each other. Hence the *Reſolution* or *Diſſolution* of Bodies into their conſtituent Corpuſcles, as in many Operations of Chemiſtry. How far this may actually obtain in Nature is not eaſy to ſay: But that Matter is infinitely diviſible in a mathematical Conſideration, is demonſtrable various Ways.

MOBILITY is that Property which all Bodies have, of being moveable or capable of changing their Situations or Places. This Property of Matter is evident to all our Senſes; and to deny it would be an Abſurdity too flagrant for any but a *Carteſian* Philoſopher.

THE VIS INERTIÆ, (as Sir *Iſaac* called it) or the *Inactivity* of Matter, is that Property of it by which it endeavours to continue in its State either of *Motion* or *Reſt*, or by which it reſiſts the Actions and Impreſſions of all other Bodies which tend to generate or deſtroy Motion therein.

ATTRACTION is a Property that we find all Matter endued with in a greater or a leſſer Degree: By this Property the Particles of Matter attract each other by a Power which cauſes them mutually to accede to, or approach each other. This Tendency of one Body to another is commonly called GRAVITATION, with reſpect to the *Act*; but in regard of the *Power*, it is called the GRAVITY or WEIGHT of Bodies.

REPULSION ſeems to be a Property belonging to the ſmall Particles of Matter univerſally; for they do not more evidently *attract* in ſome Circumſtances, than they *repel each other* in others, as will be evident by Experiments, hereafter to be exhibited.

THESE are the general Properties of Matter, which we muſt regard in our Explications of the various Phænomena of Nature, in the Senſe we have defined them. Theſe are the ſeveral *Data*, or fundamental Principles on which the Science of Philoſophy depends, and which will each of them afford an ample Field both in the *ſpeculative and practical Part.* We ſhall (for the ſake of good Method) begin with the *Attraction* of Bodies, conſider its ſeveral Species, and prove their Exiſtence and the Properties of each by Experiments.

Exp. 1.

Fig. 1.

THE *Power of Attraction*, or *Gravity* its Effect, we preſume not to define, or ſay what it is, but only that it is, or does exiſt; and the Laws of its Action we ſhall endeavour to aſſign by what may be diſcover'd by Reaſon and Experiment. To this End we muſt conſider, that *any Kind of Power or Virtue, proceeding or propagated from a Body in Right Lines every way as from a Centre, muſt decreaſe in its Strength or Energy as the Squares of the Diſtances from the Body increaſe*; for 'tis evident, the Force will be every where as the Number of Particles iſſuing from the central Body on a given Space, which Number of Particles will decreaſe as the Squares of the Diſtances increaſe. Thus the Number of Particles which at any *one Diſtance* AB, from a Point in the Body at A, falls on a Square Inch BEFG, will be *four times* as great as the Number which falls on a Square Inch CHIK at *twice* that Diſtance AC; and *nine times* as great as the Number which falls on the ſaid Square Inch DLMN at *three times* that Diſtance AD; and ſo on, as is evident from the Diagram.

HENCE, ſince we have no Reaſon to doubt but that all Kinds of Attraction conſiſt in fine imperceptible Particles or inviſible Effluvia,

via, which proceed from every Point in the Surface of the attracting Body, in all right-lined Directions every way, which in their Progreſs lighting on other Bodies, urge and ſolicit them towards the ſuperior attracting Body; therefore the Force or Intenſity of the attracting Power in general muſt always decreaſe as the Squares of the Diſtances increaſe.

HENCE alſo we may obſerve, by the way, that Light and Heat, Odours and Perfumes, which conſiſt of Particles or Effluvia that proceed every way from luminous, heated, and odoriferous Bodies, as from a Centre, have always their Forces abated according to the above Law. The Force of Sounds alſo decreaſes in the ſame Proportion, for Reaſons that will be hereafter aſſign'd.

Exp. 2.

Exp. 3.

BY virtue of attracting Power, the grand Machinery of the Solar Syſtem, and doubtleſs of all the others in the Univerſe, is effected, eſtabliſhed, and conſerved. It is therefore of the greateſt Conſequence, to be acquainted with the different Species of this univerſal Power or Agent, and to learn by Experiments the peculiar Nature, Laws, or Manner of Action in each. By the niceſt Enquiry and Obſervations of Naturaliſts there are diſcover'd *Four* different Sorts of Attraction, *viz.*

I. THE *Attraction of* COHESION, which is peculiar to the Corpuſcles or primigenial Particles of Matter, of which larger Bodies are compoſed, by the Accretion and firm Adheſion of thoſe Particles, ariſing from their ſtrong attractive Power.

II. THE *Attraction of* ELECTRICITY, which is peculiar to ſome Kinds of Bodies, as Glaſs, Amber, Sealing-Wax, *&c.* which are therefore call'd *Electrical.*

III. THE *Attraction of* MAGNETISM, or of the Loadſtone, which is peculiar to, and mutual between the Loadſtone and Iron.

IV. THE *Attraction of* GRAVITATION, which is obſervable only in the larger Compoſitions and Syſtems of Matter; as in the *Earth* and *Moon*, and the *Sun* and *Planetary Bodies* which compoſe the Solar Syſtem. Of each of theſe Species of Attraction in Order; and firſt,

OF the *Attraction of* COHESION: The Laws and Properties of this Attraction are the following. (1.) It is very diſcernible and moſt powerful in Corpuſcles, or the ſmalleſt Particles of Matter. (2.) It is mutually exerted between thoſe Particles; or they mutually attract, and are attracted by each other. (3.) The Sphere of Attraction, or Extent of this Power, is greater in ſome Particles of Matter than in others, but very ſmall at the utmoſt: For (4.) This Power is inſenſible in ſolid Bodies in the leaſt ſenſible Diſtance, acting as it were only on Contact; and therefore, (5.) It muſt be nearly proportional to the Quantity of contiguous Surfaces; or the Parts of Bodies cohere moſt ſtrongly, whoſe touching Surfaces are largeſt. 6. This Power is ſuppoſed to decreaſe much faſter than the Squares of the Diſtances increaſe; but nothing certain can be determined in this reſpect. (7.) Where the Sphere of Attraction ends, there a *Repelling* Power begins, by which the Particles, inſtead of *attracting*, *repel* and fly from each other. (8.) By this Power the ſmall Portions or Drops of a Fluid conform themſelves to a ſpherical Figure.

THE firſt and ſecond of theſe Properties are made manifeſt by
Exp. 5. various Experiments; as the ſudden Union of two contiguous
6. Drops of Mercury, Water, *&c.* The ſtrong Adheſion
of two Leaden Balls, which touch by poliſh'd
7. Surfaces; as alſo of Glaſs Planes, and Cryſtal Buttons:
8, 9. The Aſcent of Water between Glaſs Planes, and in Capillary
10, 11, 12, Tubes: The riſing of Water by the Sides of a
13, 14, 15. Glaſs Veſſel, and into Tubes of Sand, Aſhes, Sugar,
Sponge, and all porous Subſtances.

THE third of theſe Properties is evident by the Experiments of
*Exp.*16,17. Water riſing above the common Level, and Mercury's
ſinking below it, in Capillary Tubes: By the ſticking
18, 19. or adhering of Water to common Subſtances, which by
Mercury are left dry. THE

THE fourth and fifth Properties are evinced by the Experiments of the different Heights to which Fluids aſcend between Glaſs Planes unequally inclined, and in Capillary Tubes of different Bores: Alſo, by the accelerated Motion of a Drop of Oil between two inclined Planes: And likewiſe by the *Hyperbolical Curve* form'd by the Superficies of a Fluid aſcending between Glaſs Planes touching each other on one Side. *Ex.* 20, 21. 22. 23.

THE ſixth Property is not to be determined by any Experimental Proof. The ſeventh ſeems evident between *fat and oily Particles of Matter*, and thoſe of an *aqueous Nature:* But is moſt manifeſt from the Elaſtic Property of the Air, whoſe Particles compreſs'd together reſtore themſelves by this repellent Power to their firſt State: Alſo by the Aſcent of *Steam or Vapour* from humid or fluid Bodies: And laſtly, by the following Experiment, which demonſtrates alſo, *Exp.* 24. 25. 26.

THE eighth Property of this Attraction, *viz.* by Drops of Water falling on Duſt; by Drops of Dew gathering on the Tops of Graſs; and laſtly, by Quickſilver divided into ſmall Portions, which always form themſelves into perfect Spherules or Globules. 27. 28. 29.

FROM this Account of the *Attraction of Coheſion* we learn a rational Solution of ſeveral very curious and ſurprizing Phænomena of Nature: As why the Parts of Bodies adhere and ſtick ſo firmly together; why ſome are *hard*, others *ſoft*; ſome *fix'd*, others *fluid*; ſome *elaſtic*, others *void of any elaſtic Quality*; which all ariſe from the different Figure of the Particles, and the greater or leſſer Degree of Attraction conſequent thereupon. Hence the Reaſon why Flies walk on the Surface of the Water, and wet not their Feet. On this Principle we account for the Manner how Plants imbibe the nutritive Juices or Moiſture of the Earth by the Fibres of the Roots: Alſo for the Riſe of the Sap in Vegetables, and for the whole Oeconomy of Vegetation in general. Hence the *Rationale* of the various Secretions of Fluids by the Glands of an Animal Body, and their wonderful Circulation through the fine Capillary Veſſels. Hence alſo the Reaſon of Soldering and Gilding of Metals; alſo of Melting or Fuſion by Heat. Hence alſo the Exhalation of Vapours by the Heat of the Sun or Fire; the Aggregation of aqueous Particles in the Air, forming the Drops of Rain. We hence ſee the Reaſon of Diſtillation, Filtration, Diſſolution, Digeſtion, Sublimation, Precipitation, Cryſtallization, and all the other Operations of Chemiſtry and Pharmacy, which are no otherways to be accounted for. Laſtly, we find Sir *Iſaac Newton* (at the latter End of his *Optics*) gives a beautiful and clear Solution to thoſe wondrous Phænomena of ſubterranean Accenſions and Exploſions; of Volcano's and Earthquakes; of Hot Springs, Damps, and ſuffocating Exhalations in Mines, *&c.* on the Principles of this Sort of Attraction and Repulſion.

THE *Second Species of Attraction* is that of ELECTRICAL BODIES,
as *Glaſs*, *Amber*, *Sealing-Wax*, *Jet*, &c. the principal
Exp. 30. Properties of which are as follow. (1.) Thoſe Bodies
attract others which are very light, as Feathers,
Hairs, Leaf-Braſs, *&c.* (2.) The Sphere or Extent of this attracting
Power is at the Diſtance of ſeveral Feet; but, (3.) It varies
with the State of the Weather, being greateſt in hot and dry
Exp. 31. Weather, but weaker in warm and moiſt. (4.) It may
be communicated to a great Diſtance, *viz.* ſeven or
eight hundred Yards, by the Intervention of a proper
32. Body, as Hempen Strings, *&c.* (5.) This Virtue is excited
by Attrition, or hard Rubbing by the Hand or
with a Piece of Cloth, but will not be produced by the
33. Warmth of Fire. (6.) It penetrates or pervades the
Pores of Glaſs; and, (7.) It may be communicated to
34. other Bodies, ſo as to render them electrical. (8.) If
the Sphere of Attraction be interrupted on any Part, it
deſtroys

deſtroys the Efficacy of the Whole. (9.) By this Virtue *Exp.* 35.
Bodies are not only attracted, but alſo repelled alternately
to a very ſenſible Diſtance, and with a ſurpriſing
Velocity. (10.) The Body once repell'd from 36.
the Tube, will not be again attracted by it, till it has
firſt touch'd ſome other Body. (11.) Bodies attracted, 37.
and ſticking to the Tube, will be then attracted by
other Bodies not electrical; as the Finger, *&c.*
(12.) This Virtue will exert itſelf *in Vacuo*, as well as 38.
in open Air. (13.) It appears lucid, and ſparkles like 39.
Fire, in a dark Room. (14.) It is alſo ſenſible to the 40.
Ear by a crackling Noiſe, like a green Leaf in the Fire.

THE *Third Species of Attraction* is that of the MAGNET, or
LOADSTONE; the primary Properties whereof are the
following. (1.) Every Loadſtone has two Points call'd *Exp.* 41.
Poles, which emit the Magnetic Virtue. (2.) One of 42.
thoſe Poles attracts, the other repels *Iron*, but no other
Body. (3.) This Virtue is communicated to Iron very 43.
copiouſly by the Touch, which renders it ſtrongly Magnetic.
(4.) A Piece of Iron ſo touch'd by the Loadſtone, 44.
and nicely ſuſpended on a ſharp Point, will be
determined to ſettle itſelf in a Direction nearly *North*
and *South*. (5.) The End of the Needle touch'd by 45.
the *South* Pole of the Stone will point *Northwards*;
and the contrary. (6.) Needles touch'd by the Stone will 46.
dip below the Horizon, or be directed on the touch'd
Part to a Point within the Earth's Surface. This is call'd
the *Dipping Needle*. (7.) This Virtue is alſo to be 47.
communicated to Iron, by a ſtrong Attrition all one
way; whence Files, Drills, *&c.* are always found to be
Magnetical. (8.) Iron Rods or Bars acquire a Magnetic 48.
Virtue by ſtanding long in one Poſition. (9.) Fire 49.
totally deſtroys this Virtue by making the Stone or Iron red hot.

Exp. 50. (10.) This Power is exerted ſenſibly to the Diſtance of ſeveral Feet. (11.) It is ſenſibly continued through
51. the Subſtance of ſeveral contiguous Bodies or Pieces of
52. Iron, as *Keys*, &c. (12.) It pervades the Pores of the
53. hardeſt Bodies; and (13.) equally attracts the Iron *in Vacuo*, as in open Air.

THESE, and many others, are the Properties of a Body, not more wonderful than uſeful to Mankind.

LECTURE II.

THE *Fourth and laſt Species of Attraction* is that of GRAVITATION, which is evident only between large Bodies, as the Earth and Moon, and the Sun and its Planetary Attendants. The Laws of this Attraction are as fol-
Exp. 54. lows, *viz.* (1.) It is common to all Bodies, and mutual between them. (2.) It is proportional to the Quantity of Matter in Bodies. (3.) It is exerted every way from the Centre of the attracting Body in Right-lined Directions.
Exp. 55. (4.) It decreaſes as the Squares of the Diſtances increaſe. That is, if a Body at A, on the Earth's Surface, diſtant
Fig. II. *one Semidiameter* from the Centre C, weighs 3600 Pounds, it will at the Diſtance of 2, 3, 4, 5, 6, Semidiameters weigh 900, 400, 225, 145, 100 Pounds; which Numbers decreaſe as the Squares of the Diſtances 4, 9, 16, 25, 36, increaſe.

HENCE we learn that all Bodies have *Weight*, or are *heavy*; and that there is no ſuch Thing as abſolute Levity in Nature: And by the ſecond Law, the Weight of all Bodies is proportional to the Quantity of Matter they contain; and hence, ſince Bodies of equal

Bulks are found to have unequal Quantities of Matter, it evidently follows, that a *Vacuum*, or Space void of Matter, muſt neceſſarily exiſt, and that an abſolute *Plenum* is a Doctrine unphiloſophical, and equally falſe and abſurd.

ALSO, from the third Law it follows, that all Bodies deſcending freely by their Gravity, tend towards the Earth in Right Lines perpendicular to its Surface; and with equal Velocities, (abating for the Reſiſtance of the Air) as will be evident by the ſecond Law above, and what will immediately follow in *Mechanics*. *Exp.* 56.

AGAIN: Since the Attraction is always directly as the Quantity of Matter, and inverſely as the Square of the Diſtance, it follows, that were the internal Parts of the Earth a perfect Void, or hollow Concavity, a Body placed any where therein would be abſolutely light, or void of Gravity; but ſuppoſing the Earth a ſolid Body throughout, the Gravity from the Surface to the Centre will decreaſe with the Diſtance, or it will be directly proportional to the Diſtance from the Centre.

HAVING premiſed the neceſſary *Præcognita* to the Science of MECHANICS, which entirely depends on the Principle of Gravitation, we come immediately to conſider the Object thereof, *viz.* The *Nature*, *Kinds*, and various *Affections* of *Motion*, and moving Bodies; and the Structure and Mechaniſm of all kind of Machines, commonly call'd *Mechanical Powers*, whether Simple or Compound.

MOTION is the continual and ſucceſſive Change of Space, and is either *Abſolute* or *Relative*. *Abſolute Motion* is the Change of *Abſolute Space* or Place of Bodies, as the Flight of a Bird, the Motion of a Projectile, &c. But *Relative Motion* is the Change of *Relative Space*, or that which has Reference to ſome other Bodies: As of two Ships under Sail, the Difference of their Velocities is the relative Motion of the Ship ſailing faſteſt; and is that alone which is diſcernible by us. The ſame is to be underſtood of abſolute and relative Reſt. Exp. 57.

AGAIN; Motion is either *Equable* or *Accelerated*. *Equable Motion* is that by which a Body paſſes over equal Spaces in equal Times. *Accelerated Motion* is that which is continually augmented or increaſed; as *Retarded Motion* is that which continually decreaſes: And if the Increaſe or Decreaſe of Motion be equal in equal Times, the Motion is then ſaid to be *equably accelerated or retarded*. Exp. 58. 59.

THE *Celerity* or *Velocity* of Motion is that Affection by which a Body paſſes over a given Space in a given Time, or what we commonly call the *Swiftneſs* or *Slowneſs* of Motion.

THE *Momentum* or *Quantity of Motion* is all that Power or Force which a moving Body has to affect or ſtrike any Obſtacle or Impediment which oppoſes its Motion, and is equal to that impreſſed Force by which the Body is compell'd to change its Place.

SINCE the Force of a Body is greater or leſſer as the Quantity of Matter is ſo, when the Velocity of its Motion is the ſame; alſo ſince the ſaid Force in the ſame Body is proportional to its Velocity: Therefore it follows, that the *Momentum* or Force of Bodies in Motion is in the compound Ratio of their Quantities of Matter and their Velocities conjointly. Exp. 60.

Thus if one Body A ſtrike an Obſtacle X, with 3 Parts of Matter and 9 Degrees of Celerity; and another Body B ſtrike it with 5 Parts of Matter, and 7 Degrees of Celerity; the *Momenta* of the reſpective Strokes will be as 27 to 35. Fig. III.

THE general Laws of Motion, which all Bodies obſerve, are the three following, *viz.*

LAW I. *Every Body will continue in its State of Reſt, or moving*

moving uniformly in a Right Line, except ſo far as it is compell'd to change that State by Forces impreſs'd.

LAW II. *The Change of Motion is always proportional to the moving Force impreſs'd, and is always made according to the Right Line in which that Force is impreſs'd.*

LAW III. *Re-action is always equal and contrary to Action; or the Actions of two Bodies upon each other are always equal, and in contrary Directions: That is, by Action and Re-action equal Changes of Motion are produced in Bodies acting upon each other; and theſe Changes are impreſs'd towards contrary Parts.*

THE firſt of theſe Laws is founded on the *Vis Inertiæ* of Matter, whereby it is indifferently diſpoſed to perſevere in its State of Motion or Reſt. 'Tis not more evident that Matter at Reſt requires an extrinſic Power to give it Motion, than that when in Motion, the Force of ſome other Body reſiſting it is neceſſary to bring it to a State of Reſt. For want of ſuch Reſiſtance we ſee the Planets and Comets long conſerve their Motions undiminiſh'd; while moving Bowls, and Wheels, are gradually reduced to a State of Reſt, by the Friction or Rubbing of the Parts on which they move, againſt contiguous reſiſting Bodies; as will be evident by the Experiment of the *Axis in Peritrochio*, moving firſt on fix'd Boxes, and afterwards on *Friction-Wheels*. Exp. 61.

FROM this Law, and what will be farther demonſtrated hereafter, it follows, that no *perpetual Motion* can be effected, at leaſt by any human Power, with Bodies in a reſiſting Medium.

BY the *ſecond Law* we are inſtructed how to eſtimate the Sum of the Motions of Bodies moving the ſame or contrary Ways, when they directly ſtrike, or impinge on each other. Exp. 62. Alſo we hence learn the *Compoſition and Reſolution of Motion* arising from Forces impreſs'd in oblique Directions; a Doctrine of the utmoſt Uſe in Philoſophy, and the Foundation of all *Mechanics*. 63. To illuſtrate this: Let the Body B be impell'd by the Body A in the Direction *Fig.* IV. *b c*, with a Force that would, in a given Time, cauſe it to move from *b* to *c*; at the ſame Inſtant, let another Body C ſtrike it in the Direction *b d*, with a Force that will carry it from *b* to *d* in the ſame Time; then compleat the Parallelogram *b c e d*, and draw the Diagonal *b e*, that will repreſent the Direction and Diſtance through which the Body will move in the ſame Time by both the Forces conjointly.

THE *third general Law* is founded on Reaſon and Experience: We know from the Nature of Attraction or Gravity, that if a Stone fall towards the Earth, the Quantity of Motion both in the Earth and Stone is the ſame. That the Iron *Exp.* 64. attracts the Loadſtone with an equal Power of Magnetiſm, is evident by Experiment. That *Action* and 65. *Re-action* are equal between impinging Bodies, or that the ſame Quantity of Motion that is generated in one 66. Body is deſtroy'd in the other by the Stroke, whether the Bodies be *elaſtic* or *non-elaſtic*, will alſo be made apparent to the Senſes by Experiment. Whence alſo it will appear, that the Action or Effect of *elaſtic Bodies* is twice as great, as that of Bodies void of Elaſticity.

FROM this Law we have a Solution of divers *Phænomena* otherwiſe not to be accounted for: As, why ſoft and unelaſtic Bodies *retain the Impreſſions* of others, while hard and elaſtic Bodies *rebound with equal Force*, and under *equal Angles*. Hence, the Reaſon of *Rowing with Oars*, and the *Swimming of Fiſhes* in Water; alſo, the *Flying of Birds* in Air; the *Recoiling of Guns*; the retro-vertiginous Motion of the *Æolipile*; the *Hydroſtatic Paradox*; and many other Things hereafter occaſionally mention'd, are accountable for on this and no other Principle.

WE proceed next to conſider the *Nature of Motion belonging to Bodies which deſcend freely by the Force of Gravity* in *Vacuo*, or an unreſiſting *Medium*: And this Kind of Motion we ſhall find affected with the following Properties, *viz.* (1.) That it is equably accelerated. (2.) That its Velocity is always proportional to the Time of the Fall. (3.) That the Spaces paſs'd through are as the Squares of the Times or Velocities. And therefore, (4.) That the Velocity, and conſequently the *Momentum*, which is proportional thereto, is as the Square Root of the Space deſcended through. (5.) That the Space *Exp.* 67. paſs'd through the firſt Second is very nearly $16\frac{14}{100}$ Feet. (6.) That a Body will paſs over twice the Space in an 68. horizontal Direction, with the laſt acquired Velocity of the deſcending Body, in the ſame Time.

HENCE it follows, that if one Leg AB of a right-angled Triangle repreſent the *Time* of the Fall, and the other Leg BC the *Velocity* acquired at the End of the Fall; then *Fig.* V. will the Area ABC of the Triangle repreſent the Space paſs'd through. And hence the Spaces deſcended through at the End of every Second, will be as the Square Numbers 1. 4. 9. 16. 25. 36. *&c.* and therefore the Spaces paſs'd through in each Second ſeparately will be as the odd Numbers 1. 3. 5. 7. 9. 11. 13. 15. *&c.* as in the *Figure.*

THE next Sort of Motion is that of Bodies deſcending on *inclined Planes*, and *curved Surfaces*, which we find diſtinguiſh'd with the following Properties. (1.) The Motion on the *Exp.* 68. inclined Planes is equably accelerated, as ariſing from Gravity. (2.) The Force of Gravity compelling a Body, as A, to deſcend on an inclined Plane BD, is to the abſolute Force of Gravity as the Height of the Plane BC to its *Fig.* VI. Length BD. (3.) The Spaces deſcended are as the Squares of the Times. (4.) The Times in which different Planes, BD, BH, of the ſame Altitude BC are paſs'd over, are as their Lengths reſpectively. (5.) The Velocities acquired by deſcending through ſuch Planes at the loweſt Points, D, H, are all equal. (6.) Therefore if a Body deſcends from the ſame Height through ſeveral contiguous Planes, ever ſo different in Number or Situation,

tion, it will always acquire the ſame Velocity in the *Fig.* VII. loweſt Point. (7.) The Times or Velocities of Bodies deſcending through Planes ſimilarly ſituated, or alike inclined to the Horizon, as D B, E C, will be as the Square Roots of their Lengths, D B, E C.

FROM theſe Properties of Bodies deſcending on Inclined Planes, we deduce the following Corollaries, *viz.* (1.) That *Fig.* VI. the Times in which a Body deſcends through the Diameter BC, or any Chord BE of a Circle, are equal. Hence, (2.) All the Chords of a Circle are deſcribed in equal Times. (3.) The Velocities acquired in deſcending through any Arch of a Circle E C, in the loweſt Point C, is equal to that which would be acquired in falling through the ſame perpendicular Height BC. (4.) The Velocities acquired in de- *Fig.* VII. ſcending through the Chords I C, E C, of a Circle are, at the loweſt Point C, as the Lengths of thoſe Chords. (5.) The Times of Deſcent through Chords of ſimilar Arches, D B, E C, are as the Square Roots of the Semidiameters A B, A C, of the reſpective Circles.

Exp. 70. FROM theſe Properties, and their Corollaries, the Doctrine of Pendulums is derived. A *Pendulum* is any *Fig.* VIII. Body B, ſuſpended upon, and moveable about a Point A, as a Centre. The Nature of a Pendulum conſiſts in the following Particulars. (1.) The Times of the Vibrations of a Pendulum in very ſmall Arches are all equal. (2.) The Velocity of the Bob in the loweſt Point will be nearly as the Length of the Chord of the Arch which it deſcribes in the Deſcent. (3.) The Times of Vibration in different Pendulums, A B, A C, are as the Square Roots of their Lengths. (4.) Hence *Exp.* 71. the Lengths of Pendulums A B, A C, are as the Squares of the Times of their Vibrations. (5.) The Time of one Vibration is to the Time of Deſcent through half the Length of the Pendulum, as the Circumference of a Circle to its Diameter.

Distances	Squares	Forces
AB = 1	1	9.
AC = 2	4	2¼
AD = 3	9	1.

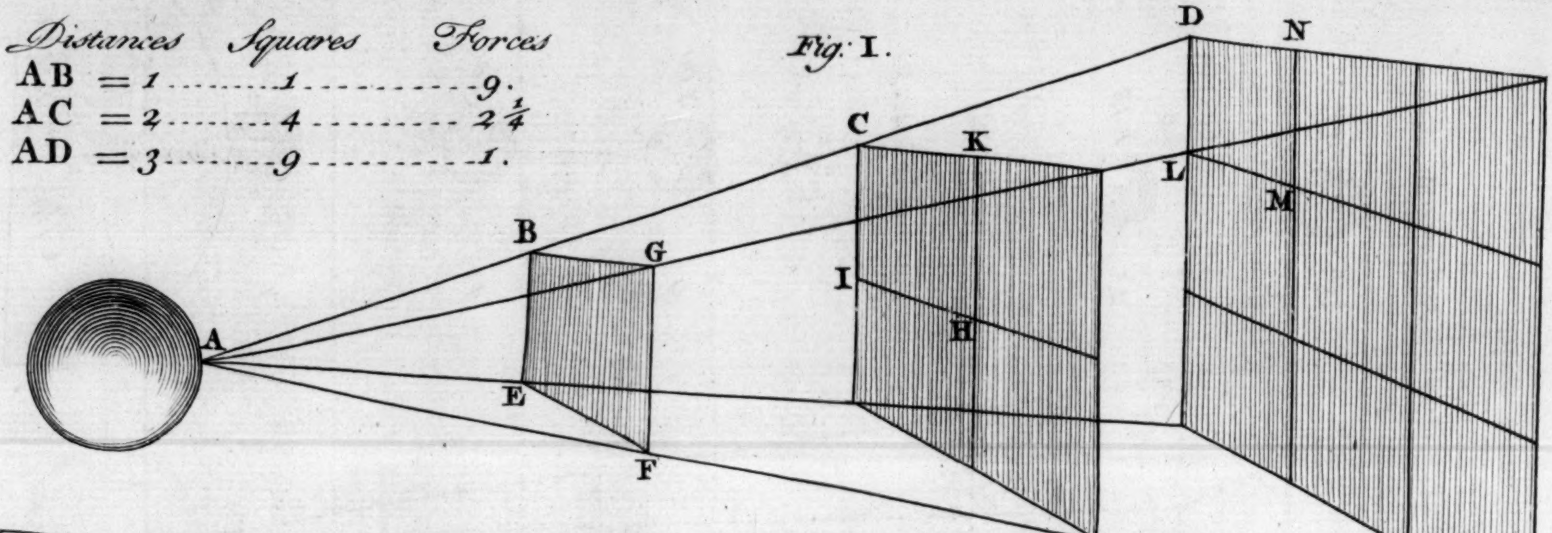


Fig: I.

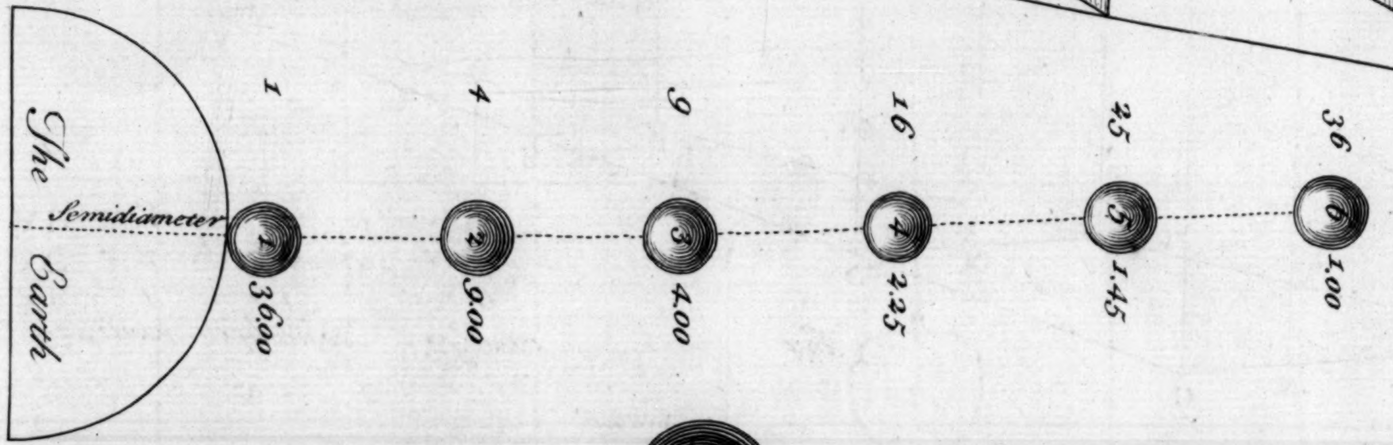


Fig: II.

Quantity of Matter Q = 3
Celerity C = $\frac{9}{27}$
Momentum M =

Quantity of Matter Q = 5
Celerity C = $\frac{7}{35}$
Momentum M =

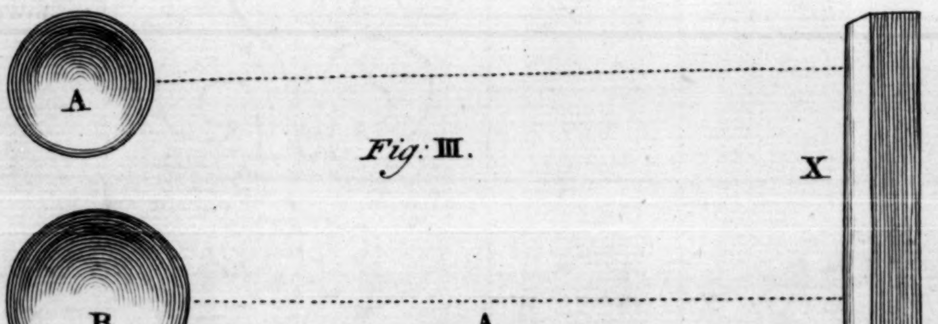


Fig: III.

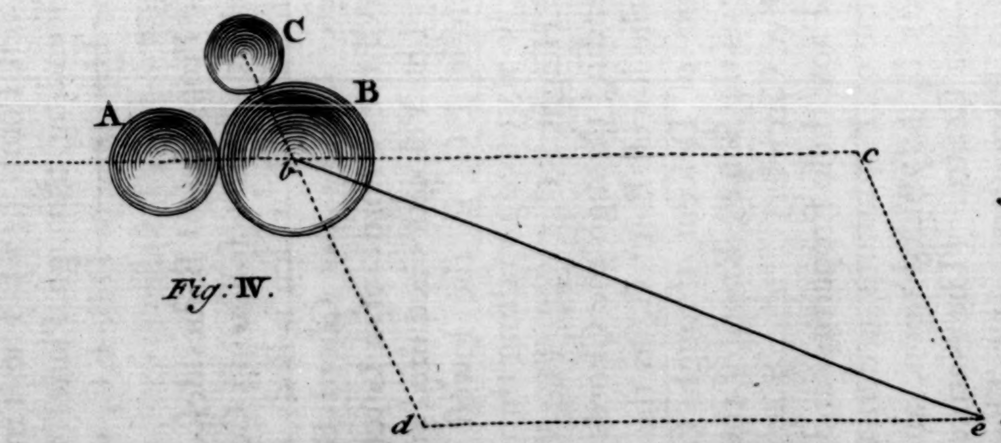


Fig: IV.

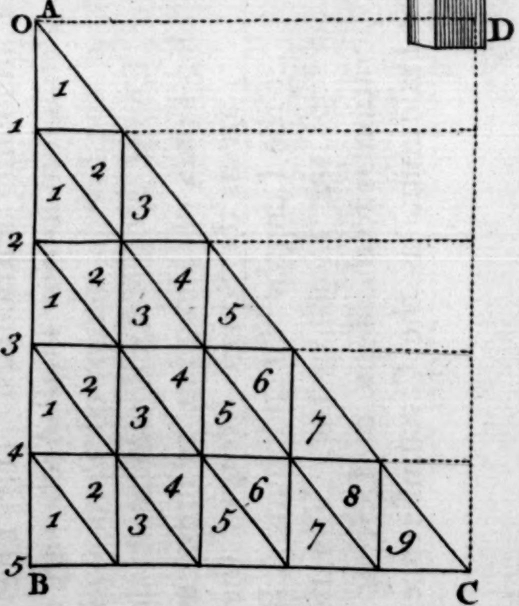


Fig: V.

E: Bowen sc.

meter. (6.) Whence the Length of a Pendulum vibrating Seconds will be found 39 Inches nearly; and of an Half-Second Pendulum 9,8 Inches. (7.) An uniform homogeneous Body BG, as a *Rod*, *Staff*, &c. which is *one third Part* longer than a Pendulum AD, will vibrate in the ſame Time with it. (8.) This *Centre of Oſcillation* E in the Rod, is alſo the *Centre of Percuſſion*, or that Point in which the Force of the Stroke is the greateſt poſſible. *Exp.* 72. *Fig.* IX. *Exp.* 73. 74.

FROM theſe Properties of the Pendulum we may diſcern its Uſe as an univerſal *Chronometer*, or Regulator of Time, as it is uſed in Clocks and ſuch-like Machines. By this Inſtrument alſo we can meaſure the Diſtance of a Ship, by meaſuring the Interval of Time between the Fire and the Sound of the Gun; alſo the Diſtance of a Cloud, by numbering the Seconds or Half-Seconds between the Lightning and Thunder. Thus, ſuppoſe between the Lightning and Thunder we number 10 Seconds; then, becauſe Sound paſſes through 1142 Feet in one Second, we have the Diſtance of the Cloud equal to 11420 Feet. Again; the Height of any Room, or other Object may be meaſured by a Pendulum vibrating from the Top thereof. Thus, ſuppoſe a Pendulum from the Height of a Room vibrates three times in one Second; then ſay, As 1 is to the Square of 3, *viz.* 9, ſo is 39,2 to 352,8 Feet, the Height required. Laſtly, by the Pendulum we diſcover the different Force of Gravity on diverſe Parts of the Earth's Surface, and thence the *true Figure of the Earth*. *Exp.* 75. *Exp.* 76. *Exp.* 77.

THE greateſt Inconvenience attending this moſt uſeful Inſtrument is, that it is conſtantly liable to an Alteration of its Length from the Effects of *Heat and Cold*, which very ſenſibly expand and contract all Metalline Bodies, as will be very evident by the *Pyrometer*. *Exp.* 78.

WHEN Pendulums were firſt applied to Clocks, they were made very ſhort; and the Arches of the Circle deſcribed being large, the Times of Vibration through different Arches could not, in that Caſe, be equal; to effect which, the Pendulum was *Exp.* 79. contrived to vibrate in the Arch of a *Cycloid*, the Property of which Curve is, *that a Body will deſcend from any Part thereof to the loweſt Point in the ſame Time*, and ſooner than by any other Way.

THE Motion of PROJECTILES comes next to be conſider'd. *Fig.* X, XI. A *Projectile* is any Body A, thrown or projected in an upright, oblique, or horizontal Direction; as, a *Stone* from the Hand, an *Arrow* from the Bow, or a *Ball* or *Bomb* from a Cannon or Piece of Ordnance. The Force with which the Body is projected is call'd the *Impetus*, and the Diſtance to which it is thrown is call'd the *Horizontal Random* or *Amplitude* of the Projection.

EVERY Projectile is acted upon by two Forces or Powers, *viz.* the *Impetus* of the *projectile Force*, and that of *Gravity*. *Exp.* 80. By the firſt, the Body paſſes over *equal Spaces*, AB, BC, CD, *&c. in equal Times*; and by the ſecond, it deſcends through Spaces AG, AH, AI, *&c.* which are as the *Squares of the Times*; and therefore by theſe two Forces compounded the Body will deſcribe, not a *Right Line*, but a *Curve* AQ, and of that Sort which we call a *Parabola*; and this will be the Caſe in all Directions but that in the Perpendicular, *Exp.* 81. when the Path of the Projectile will be (to Appearance) a Right Line. The greater the Angle of Elevation KAM of the Cannon is, *Fig.* XII. the greater will be the Height DB to which the projected Body will ariſe. *Exp.* 82. Alſo, the greater will be the Diſtance or Amplitude of the Projection, till the ſaid Angle becomes equal to 45 Degrees KAO; upon which Elevation the Random AC will be the greateſt poſſible, and equal to twice the Altitude AG of the perpendicular Projection. On any Elevation AM or A *M*, equally above or below 45 Degrees, as on 40 and 50, 30 and 60, 20 and 70 Degrees, the Random A C will be the ſame; which Caſe an Engineer frequently finds of very great Uſe.

Exp. 83.

If the Object be ſituated above the Horizon, then in order to ſtrike it, let a Piece of Looking-glaſs be fix'd to the Cannon perpendicular to its Axis; and holding a Plumb-Line over the Glaſs directly under the Eye, the Cannon is to be elevated till the Object appears exactly under the Plummet, and there fix'd; if then it be diſcharged, it will ſtrike the Object as required.

Exp. 85.

From what has been ſaid, we may eaſily underſtand how a Body projected upright from the Earth's Surface does really deſcribe a Parabola, though to Appearance it aſcends and deſcends in a Right Line. For it is urged by two Forces, *viz.* the Projectile upwards, and the Force ariſing from the Motion of the Earth about its Axis from *Weſt* to *Eaſt*; in which Caſe it muſt neceſſarily deſcribe a Parabola, as will be evident from Experiment.

Exp. 85.

I shall in the laſt Place conſider the Nature of *Circular Motion* and *Central Forces*. If a Body A be ſuſpended at the End of a String A C, moveable about a Point or Pin C as a Centre, and in that Poſition it receive an Impulſe or Blow in an horizontal Direction, it will be thereby compell'd to deſcribe a Circle about the central Pin: While the circular Motion continues, the Body will have a continual Endeavour to recede or fly off from the Centre, which is call'd its *Centrifugal Force*, and ariſes from the *horizontal Impetus*; with this Force it acts upon the fix'd Centre Pin, and that, by its Renitency or Immobility, re-acts with an equal Force on the Body by means of the String, and ſolicits it towards the Centre of Motion, whence it is call'd the *Centripetal Force*; and when we ſpeak of either, or both of

Exp. 86.
Fig. XIII.
Exp. 87.

them indefinitely, they are call'd the *Central Forces* of the revolving Body.

IT is of the laſt Importance to underſtand the Nature of this Kind of Motion, ſince by it all the Machinery of the Planetary Syſtem is perform'd, as will be eaſy to underſtand, if, for the revolving Body, we ſubſtitute a Planet; for the Centre, we place the Sun; for the *Centripetal Force*, or String, its Power of Attraction; and for the *Projectile Force*, the Almighty Power of God in the firſt Creation of Things.

Exp. 88.

THE Theory of this Species of Motion is compriſed in the following Propoſitions, *viz.* (1.) The projectile Force AH is infinitely greater than the centrifugal Force HE. (2.) The central Force is proportional to the Quantity of Matter in the revolving Body A, all other Things being equal. (3.) If two equal Bodies A, B, deſcribe unequal Circles AM, AN, in equal Times, the central Forces will be as the Diſtances AC, BC, from the Centre C. (4.) If equal Bodies deſcribe unequal Circles with equal Celerities, the central Forces will be inverſely as the Diſtances. (5.) If equal Bodies deſcribe equal Circles, the central Forces will be as the Squares of the Celerities. (6.) If equal Bodies deſcribing unequal Circles have their central Forces equal, their Periodical Times will be as the Square Roots of the Diſtances. (7.) If equal Bodies deſcribe unequal Circles with equal Celerities, the Periodical Times will be as the Diſtances directly. (8.) Therefore the Squares of the Periodical Times are proportional to the Cubes of the Diſtances, when neither the Periodical Times nor the Celerities are given. And in that Caſe, (9.) The central Forces are as Squares of the Diſtances inverſely.

THESE are the Theorems of circular Motions, the two laſt of which are found by Aſtronomers to be ſtrictly obſerved by every Body of the Planetary and Cometary Syſtem. For Example: The Periodical Time of *Venus* is 225 Days, and that of the *Earth* 365; the Squares of which Numbers are 50625 and 133225:

Again, the Diſtance of *Venus* from the *Sun* is to that of the *Earth* as 72 to 100; the Cubes of which Numbers are 373248 and 1000000; but 50625 : 133225 :: 373248 : 1000000; that is, the Squares of the Periodical Times are as the Cubes of their Diſtances, very nearly. From hence alſo it will eaſily appear, that Bodies under the Equator have the greateſt centrifugal Force, which there acts in direct Oppoſition to Gravity, and diminiſhes towards the Poles, with the Squares of the Diſtances from the Earth's Axis. Hence alſo it is evident, that if ever the Earth was in a fluid State, and at the ſame Time moving about its Axis, it muſt neceſſarily put on the Figure, not of a perfect Sphere or Globe, but of an oblate Spheroid, flatted towards both the Poles; as will be manifeſtly ſhewn by Experiment. *Exp.* 89.

LECTURE III.

HAVING conſidered the Nature of every Kind of Motion, with the Properties of each, we ſhould have come immediately to conſider the *Mechanical Powers* or *Machines*, but that ſomething ſtill remains to be premiſed thereto, relating to the *Centres of Magnitude*, of *Motion*, and of *Gravity* in Bodies.

THE *Centre of* MAGNITUDE is that Point which is equally diſtant from all the external Parts of the Body: And in Bodies that are uniform and homogeneal, it is the ſame with *Exp.* 90.

THE *Centre of* MOTION, which is that Point which remains at Reſt, while all the other Parts of the Body move about it: And this is again the ſame in uniform Bodies, of the ſame Matter throughout, as *Exp.* 91.

THE *Centre of* GRAVITY, which is that Point about which all the Parts of a Body do in any Situation exactly balance each other. *Exp.* 92.

THIS Centre of Gravity in Bodies is of the greateſt Conſequence to be well underſtood, as being the ſole *Principle of all Mechanical Motions.* The particular Properties hereof are as follow. *Exp.* 93. (1.) If a Body be ſuſpended by this Point, as the Centre of Motion, it will remain at Reſt in any Poſition indifferently. 94. (2.) If a Body be ſuſpended in any other Point, it can reſt only in two Poſitions, *viz.* when the ſaid Centre of Gravity is exactly above or below the Point of Suſpenſion. 95. (3.) When the Centre of Gravity is ſupported, the whole Body is kept from falling. (4.) Becauſe this Point has a conſtant Endeavour to deſcend to the Centre of the Earth; therefore, (5.) When this Point is at Liberty to deſcend, the whole Body muſt alſo deſcend or fall, either by ſliding, rolling, or tumbling down. *Exp.* 96. 97. (6.) The Center of Gravity in regular, uniform, and homogeneal Bodies, as *Squares*, *Circles*, *Spheres*, &c. is the middle Point in a Line connecting any two oppoſite Points or Angles. 98. (7.) In a Triangle it is in a Line drawn from any Angle biſecting the oppoſite Side, one Third of the Length diſtant from that Side or Baſe. 99. (8.) It is alſo one Third of the Side diſtant from the Baſe of an hollow Cone. 100. (9.) But in a ſolid Cone it is one Fourth of the Side diſtant from the Baſe. (10.) In the Human Body, the Centre of Gravity is ſituated in that Part which is call'd the *Pelvis*, or in the Middle between the Hips.

HENCE the Solution of ſeveral very curious *Phænomena* will be evident with the leaſt Attention; as why ſome Bodies ſtand more firmly on their Baſes than others; *Exp.* 101. why ſome ſtand firmly in an inclined Poſition; why ſome

Bodies fall in one manner, ſome in another; why ſome may ſeem
to riſe, while the Centre of Gravity really deſcends, as
the *rolling Cone*, and *Cylinder*. Hence the Form of *Exp.* 102, 103.
that particular Bucket which deſcends empty with the 104.
Mouth downwards, but is drawn up full with the
Mouth upwards. Hence alſo it appears that a Waggon 105.
loaded with heavy Matter, as Iron, Stone, &c. will
go ſafely on the Side of a Hill or riſing Ground, where a Load of
Hay or Corn would be overturn'd. Again, we hence
ſee the Reaſon why no Man, ſtanding ſtill, can move *Exp.* 106.
or ſtir, without firſt moving the Centre of Gravity out
of its Place; alſo, why we ſtand firmly, while the Center of Gravity
falls between, or on the Baſe Line of the Feet; and how neceſſarily
we fall, when the Centre of Gravity falls on one Side or
other of the ſame: With many other Particulars, which naturally
reſult from this Principle.

If two or more Bodies in Motion be connected together, as
Chain-Shot, &c. or any how depend on each other,
they will have a *Common Centre of Gravity*, which *Exp.* 107.
will be a Point in the Line joining the Centres, ſo ſituated,
that its *Diſtance from the ſaid Centres will be reciprocally
as the Quantity of Matter in each Body*.

Whence, ſince the Earth and Moon are to each other as about 40 to 1, and the Diſtance of the Moon 60 Semidiameters of the Earth, the Diſtance of the common Centre of Gravity of the Earth and Moon will be found about 1840 Miles from the Earth's Surface; and it is this common Centre of Gravity that deſcribes the *Annual Orbit* about the Sun, and not the Earth itſelf, as is commonly ſaid and thought.

In like manner there is a common Centre of Gravity of the
Sun and all the Planets which circulate about him; and *Exp.* 108.
were they all placed in a Right Line on one ſide the
Sun, then would the common Centre of Gravity of the whole
Syſtem

Syſtem be diſtant from the Sun's Surface eight Tenths of his Semidiameter: And it is about this common Centre of Gravity, and not about the Sun, that not only all the Planets, but even the Sun itſelf, do conſtantly move.

THE common Centre of Gravity of any Number of Bodies being ſupported, none of thoſe Bodies can fall; which is the Reaſon of many very ſurpriſing Appearances in Nature, as that common Experiment of ſuſpending a Bucket of Water at the End of a Stick off the Table without falling; the Toy of the Man a ſawing, &c. *Exp.* 109. 110. 111.

WE have now premiſed every thing neceſſary for underſtanding the Nature of thoſe Inſtruments which are commonly call'd MECHANICAL POWERS or MACHINES: They are Six in Number, as follow, *viz.* The *Lever*, the *Pulley*, the *Wheel and Axle*, the *Inclined Plane*, the *Wedge*, and the *Screw*. They are call'd *Mechanical Powers*, becauſe they increaſe our Power of moving or raiſing heavy Bodies, which are often unmanageable by any natural human Strength, not thus aſſiſted; and of two or more of theſe all other compound Inſtruments and Machines are contrived and compoſed.

I. A LEVER is any inflexible Line, Rod, or Beam, moveable about or upon a fix'd Point, (call'd the Prop or *Fulcrum*;) upon one End of which is the Weight to be raiſed, at the other End is the Power applied to raiſe it, as the Hand, &c. *Exp.* 112. Since (as we have before proved) the *Momentums of the Weight, and Power, are as the Quantities of Matter in each multiplied by their reſpective Celerities; and the Celerities are as the Diſtances from the Centre of Motion, and alſo as the Spaces paſs'd through in a perpendicular Direction in the ſame Time*; it muſt follow, *that there will be an Equilibrium between the Weight and Power, when they are to each other reciprocally as the Diſtances from* *Exp.* 113.

from the Center, *or as the Celerities of the Motions*, or *as the perpendicular Aſcent and Deſcent in the ſame Time*; and this univerſally in all Mechanical Powers whatſoever, which is therefore the *fundamental Principle* of all *Mechanics*.

To illuſtrate this, let A B be a Lever ſuppoſed without Weight, and F its *Fulcrum* or Prop; let W be a *Fig.* XIV. Weight ſuſpended from the End A, and P the Power applied to the other End B. Then let the Lever be moved into the Situation C D, 'tis evident the Velocities of the Points A and B will be as the Arches A C and B D deſcribed in the ſame Time: Alſo the perpendicular Diſtances, through which the Weight W and Power P move in the ſame Time, are C E and G D, which are as the Arches A C and B D; and theſe are as the Radii CF and DF, which are equal to A F and B F. Therefore in order to produce an *Equilibrium*, it muſt be $W \times AC = P \times BD$, or $W \times CE = P \times DG$, or $W \times AF = P \times BF$: Conſequently, $P : W :: AC : BD :: CE : DG :: AF : BF$. Note, that in eſtimating the Effects of Machines, we regard only the Diſtances of the Power or Weight which are perpendicular to the Lines of Direction in which thoſe Powers act, as F B, or F M, which are perpendicular to the Directions P B and L M.

THE *Lever* is of Five Kinds. (1.) The common *Exp.* 114. Sort, where the Prop is between the Weight and the Power, but neareſt the former. (2.) When the Prop 115. is at one End, the Power applied at the other, and the Weight between both. (3.) When the Prop is at one 116. End, the Weight at the other, and the Power applied between both. (4.) The bended Lever, which differs 117. only in Form from the firſt Sort. (5.) When the Prop is placed at an equal Diſtance between the Weight and the Power, and this is commonly call'd

THE BALANCE, whoſe Uſe is, with a Pair of Scales, *Exp.* 118. to bring one Body to an equal Weight with another that

is

Exp. 119. is a Standard. The *Proportional Balance* is without
Scales, and is uſed for diſcovering or aſſigning any Pro-
120. portion of Weight in Bodies. The *Falſe Balance*
makes Bodies of unequal Quantities of Matter appear
121. to have equal Weight. Laſtly, the *Statera*, or *Roman*
Balance, commonly call'd the *Steelyard*, is a moſt uſe-
ful Kind of univerſal Balance, the Structure and Uſe whereof
will be eaſy to underſtand from the above Principles.

II. THE PULLEY is an Inſtrument well known;
Exp. 122, if ſingle, it is reduced to the Lever of the fifth Sort,
123, 124, or Balance, and ſo affords no Advantage in raiſing
125, 126, Weights. If two or more be combined together in the
127, 28, common Way, *Then the Power is to the Weight as U-*
129. *nity to the Number of Ropes which go to the Pulleys of the lower Box.* But there are different Ways of applying Pulleys, whoſe *Advantage or Power* will be obvious from the Structure of the ſeveral Sorts of *Tackles*, and the Experiments with them.

III. THE WHEEL and AXLE (commonly call'd
Exp. 130. the *Axis in Peritrochio)* is the third Mechanical Power.
We eaſily ſee by its Make, it is reducible to a Lever of the firſt Sort; and that therefore *the Power is to the Weight, as the Diameter of the Axle to the Diameter of the Wheel*, in an *Equilibrium* in this Machine.

IV. THE INCLINED PLANE is the fourth
Exp. 131, Mechanical Power, and from a due Conſideration of it,
132. it will appear, that, for an *Equilibrium*, *the Power muſt be to the Weight, as the Height of the Plane to the Length.*

V. THE WEDGE is only a double Inclined Plane,
Exp. 133. intended to ſeparate the Parts of Wood, *&c.* which
ſtrongly cohere together; whence, in the common Form of it, *the Power will be to the Reſiſtance to be overcome, as half the Thickneſs of the Wedge to the Length thereof.*

VI. THE SCREW is the laſt mention'd Mechanical Power, whoſe Uſe is both for *Preſſure* and *raiſing of Weights*, but chiefly the former. *The Power is to the Weight, as the Velocity of the Weight to the Velocity of the Power*, that is, *as the Diſtance between two Threads of the Screw to the Circumference of a Circle deſcribed by the Power.* Exp. 134, 135.

WE have here conſider'd the Action or Effect of each of theſe Machines, as they would anſwer to the Strictneſs of the Mathematical Theory, were there no ſuch thing as Friction or rubbing of Parts which move upon each other, by which means *one Third Part* of the Effect of the Machine is, at a Medium, deſtroy'd, as will be evident by an Experiment of the Inclined Plane. And farther, concerning Friction we are to obſerve, that it is not proportional to the *Quantity of Surface*, but *to the Weight* of the incumbent Part; as we ſhall alſo ſhew by Experiment. Exp. 136. 137.

As to *Compound Engines and Machines*, they are as *numerous*, as they are *various* in their Structure; concerning all which we may obſerve in general, that they conſiſt of one, two, or more of the Simple Powers combined together; that in moſt of them the *Axis in Peritrochio*, the *Lever*, and the *Screw* are the conſtituent Parts; that in all, a certain Power is applied to produce an Effect of much greater Moment; and that, in the laſt Place, it is known, that the greateſt Effect or Perfection of the Machine is then, when it is ſet to work with *four Ninths* of that Charge which is equivalent to the Power, or will but juſt keep the Machine *in Equilibrio.*

THE *Common* JACK is a compound Engine, where the Weight is the Power applied; the Friction of the Parts, and the Weight with which the Spit is charged, is the Force to be overcome; and a ſteady, uniform Motion, by means of the Fly, is the End or Intention of the Machine. Exp. 138.

IN CLOCKS, WATCHES, &c. the Power is the Weight or Spring; the Force to be overcome is the Friction of the numerous Parts, which are chiefly a Combination of Wheels and Axes, whoſe Uſe is to divide a large Portion of Time, as a *Day* or an *Hour*, into very minute equal Parts, as *Minutes*, *Seconds*, &c. and to point out thoſe Diviſions by an equable Motion of a proper Hand or Index round a graduated Circle. *Exp.* 139.

IN the ORRERY and COMETARIUM, the whole Machinery is a Compages of Wheels of various Sizes, ſuitably contrived and adapted to produce circular and elliptical Motions of Bodies repreſenting the *Planets* and *Comets*, in ſuch Periods of Time as are exactly proportional and correſpondent to the reſpective Motions of the Heavenly Bodies which they repreſent; alſo their ſeveral Phaſes, Poſitions of the Orbits, and other Affections, ſo as to be a perfect *Microcoſm*, or *Solar Syſtem* in Miniature. *Exp.* 140. 141.

IN WATER-MILLS, the *Momentum* of the falling Water is the Power; the Force to be overcome is the great Attrition of the two Stones in grinding the Corn, &c. which is effected wholly by a Complication of Wheels and Axles. A Query may here be put, Why, ſince the Power conſtantly acts upon the Wheel, the Motion of the Wheel ſhould be equable, and not accelerated? The Anſwer is, The Increments of Velocity keep riſing, till the *Momentum* of the Wheel bears a certain Ratio to the Reſiſtance of the Machine; after which they are all deſtroy'd as faſt as they ariſe, and the Wheel goes on with an uniform Motion. *Exp.* 142.

IN WIND-MILLS the Mechaniſm is the ſame, only the Vanes or Sails are to be conſider'd as a *Wheel on the Axle*, actuated by the Power of the Wind. In this Machine we have only to conſider the Poſition of the Sails, and the Power of the Wind. As to the former, if the Sails ſtand *right* before the Wind, it cannot affect them at all; if they ſtand *Exp.* 143.

direct to the Wind, the Mill will be blown down, at leaſt, the Sails could have no Power to move round; they muſt therefore be placed *oblique* to the Wind, and that under an Angle of 54 Degrees and 44 Minutes, for the greateſt Advantage.

As for the Power of the Wind on the Sail, it is always as the Direction of the Wind, and the Number of Particles which ſtrike on the Area of the Sail in a given Time; both which are as the *Sine of the Angle of Inclination*; and therefore on Windmill Sails, the *Force of the Wind increaſes or decreaſes with the Squares of the Sine of the Angle of Incidence.* *Exp.* 144.

HENCE, in reſpect to the *Sails of a Ship*, ſince the Force of a *direct Wind* is to that of a Wind blowing obliquely, *as the Square of Radius to the Square of the Sine of the Angle of Incidence*, it will follow, *that two equal Sails ſet oblique to the Wind are more advantageous than one ſet directly before it*; provided the Angle of Obliquity or Inclination exceeds 45 Degrees. *Exp.* 145.

IT is to be obſerved, that in order to turn a Ship about in the leaſt Time, or with the greateſt Celerity poſſible, the Rudder ought to make an Angle with the Stern of 54 Degrees, 44 Minutes: And alſo, that this is the Angle which the *Gates of a Lock or Sluice* upon a River ought to make with the Sides of the River, in order to reſiſt the Water with the greateſt poſſible Force. *Exp.* 146.

I SHALL conclude this Lecture with a few Words concerning WHEEL-CARRIAGES, the whole Doctrine whereof (as it ſtands on a *Mathematical Theory*) may be reduced to the following Particulars, *viz.* (1.) Wheel-Carriages meet with leſs Reſiſtance than any other. *Exp.* 147. (2.) The larger the Wheels, the eaſier is the Draught of the Carriage. 148. (3.) A Carriage upon four large Wheels, of equal Size, is drawn with leſs Force than with two of thoſe Wheels, 149.

and two of a leſſer Size. (4.) If the Load be laid on *Exp.* 150. the Axle of the larger Wheels, it will be drawn with leſs Force than if laid on the Axis of the leſſer Wheels; contrary to the common Notion of *loading Carriages before.* *Exp.* 151. (5.) The Carriage goes with much leſs Force on *Friction-Wheels*, than in the common way; all which will be confirmed by Experiments.

LECTURE IV.

HYDROSTATICS.

HYDROSTATICS is that Part of Philoſophy which treats of the Nature, Gravity, and Preſſure of Fluids. A Fluid is a Subſtance whoſe Particles yield to the leaſt partial Preſſure, or Force impreſs'd. And hence 'tis reaſonable to infer, that thoſe Particles muſt be exceeding ſmall, ſmooth, round, and ponderous Bodies; and obſerve all the Laws of Motion and mutual Action in common with thoſe of all other Matter. The following are the Laws and Properties of fluid Bodies.

I. *All Fluids are incompreſſible, except Air*; or, *they cannot by any Force be compreſs'd into a leſs Space than what they naturally poſſeſs*; as is proved by the *Florentine Experiment* *Exp.* 152. of filling a Globe of Gold with Water, which when preſs'd with a great Force, cauſes the Water to tranſude or iſſue through the Pores of the maſſy Gold, in Form of Dew, all over its Surface.

II. *Air is the only compreſſible Fluid in Nature*; for by an equal Force or Preſſure over all its Surface it may be reduced within leſs Dimenſions; which is owing to its *Elaſticity*, of which we ſhall treat in PNEUMATICS.

III. *All Fluids gravitate, or weigh, in proportion to their Quantity of Matter*; and that not only in the Air, or *in Vacuo*, but *in proprio Loco*; or, a Fluid weighs the ſame communicating with a Quantity of that Fluid, as *in Vacuo*; which all Philoſophers (till very lately) have denied. *Exp.* 153.

IV. *From the Gravity of Fluids ariſes their Preſſure, which is always proportional thereto*; and ſince we may ſuppoſe all the Particles of a Fluid to have equal Bulk and Weight, the Gravity of the Fluid, and conſequently its Preſſure, *will be always proportional to the Altitude or Depth thereof*. Whence the Weight and Preſſure of Fluids on the Bottoms of Veſſels, *&c.* muſt be equal. *Exp.* 154.

V. *The Preſſure of Fluids upwards is equal to the Preſſure downwards*, at any given Depth. To illuſtrate this, and the foregoing Propoſition, let A B C D be a Veſſel of Water, whoſe Altitude E F ſuppoſe to conſiſt of a Column of 10 aqueous Particles: Then, 'tis evident, the firſt or uppermoſt Particle 1 can affect the next Particle 2 only by its Weight or Preſſure, which therefore is as 1; and ſince that Particle 2 is immoveable, and Action and Re-action equal and contrary, the ſaid Particle 2 will re-act upwards upon the Particle 1 with a Force which is as 1. In the ſame manner the Particle 2 acts on the Particle 3 by Preſſure downwards, with 2 Degrees of Force, ariſing from its own Weight and that of the Particle above it; and accordingly it is preſs'd upwards with an equal Force by the Re-action of the Particle 3: And ſo of all the reſt. Wherefore the Propoſitions are manifeſt. *Fig.* XV.

VI. *The Preſſure is upon all Particles of the Fluid at the ſame Depth equal in every Part*; or, *the Particles of a Fluid, at the ſame Depth, preſs each other every way, and in all Directions, equally.* For if any Particle were *Exp.* 155.

were preſs'd more on one Part than another, it muſt give way, or yield, till the Preſſure became every way equal; otherwiſe an inceſſant inteſtine Motion of the Particles would enſue, which is abſurd, and contrary to Experience.

VII. FROM the mutual Preſſure and equal Action of the Particles it follows, *that the Surface of a Fluid muſt be perfectly ſmooth and even*; for ſhould any Part ſtand higher than the reſt by any Force, as Attraction, &c. it would immediately ſubſide to a Level with the other Part by the Force of its own Gravity, when that Force is removed. *Exp.* 156.

VIII. THE Figure of the Surface of all Fluids is ſpherical or convex; for all the Particles equally gravitating towards the Center of the Earth, will take their Places from it at equal Diſtances at the Surface, and ſo form a Part of the Superficies of a Sphere, equal to the Bulk of the Earth.

IX. SINCE Fluids preſs equally every way, the Preſſure of each Particle againſt the Side of a Veſſel will be proportional to its Altitude; and conſequently the Preſſures of the Particles 1, 2, 3, 4, &c. of a perpendicular Column againſt the Side BC will be as a Series of Numbers in Arithmetical Progreſſion, whoſe firſt Term is 0; therefore *the Sum of all the Preſſures is equal to the Number of Preſſures multiplied by half the greateſt Preſſure:* But the Number of Preſſures is as the Number of Particles, or Altitude of the Fluid BC; alſo the greateſt Preſſure is as the ſame Altitude: *Wherefore the total Preſſure againſt the Side of a Veſſel is as the Square of the Altitude of the Fluid.* *Fig.* XV.

X. HENCE if the Veſſel AC be of a Cubical Form, the Preſſure againſt a Side BC is half that upon the Bottom CD; and conſequently, *the total Preſſure againſt the Sides and Bottom is equal to three times the Weight of the Fluid on the Bottom of ſuch a Veſſel.*

XI. THE *Weight, Preſſure, or Effect of a Fluid upon the Bottom* DE *of any Veſſel* ACDEF, *is proportional to the Altitude* AE *only, and not to the Quantity of the Fluid in the Veſſel:* For every Column of Particles GH, which preſſes downwards on the Side of the Veſſel EF, has its Force deſtroy'd by the equal Re-action of the ſubjacent Particle H in the Side, and ſo cannot at all affect the Bottom of the Veſſel. Again; the Preſſure of any Column of Particles LM upwards, againſt the Side of a Veſſel CD, is equally re-acted by the Particle of the Veſſel over it, and ſo its Force or Preſſure on the Bottom muſt be the ſame as that of another Column of Particles AB of equal Altitude with the Fluid: Whence the Propoſition is evident. *Fig.* XVI.

XII. HENCE *a very ſmall Quantity of a Fluid, as* APRS, *may be made to counter-balance or be equivalent to the Weight or Force of any given Quantity* TKGV, *how great ſoever*; as will be manifeſt from Experiment. *Exp.* 157.

XIII. WHEN any Body is immerſed in a Fluid, *it loſes juſt ſo much of its Weight as is equal to the Weight of an equal Bulk of the Fluid*; but the *Weight loſt by the Body is gain'd by the Fluid,* which will be ſo much heavier than before; as will appear from Experiments. *Exp.* 158. 159.

XIV. IF any Body E could be found without Weight, *it would, if placed on the Surface of a Fluid* AB, *float thereon without any Part immerſed therein*; for being devoid of Gravity, it could have no Force to diſplace any Particles of the Fluid, and ſink therein. *Fig.* XVII. *Exp.* 160.

XV. IF *any heavy Body* F, *lighter than an equal Bulk of the Fluid, be placed on its Surface, it will ſink or deſcend therein, till it has removed or diſplaced ſo much of the Fluid whoſe Weight is equal to that of the Body:* For then the Preſſure upwards and downwards on the under Surface of the Body is equal; and conſequently the Body will be there quieſcent, *Exp.* 161.

eſcent, or in *Equilibrio* with the Fluid. Hence *the whole Solid is to the immerſed Part, as the ſpecific Gravity of the Fluid to that of the Solid.*

XVI. IF *a Solid, as* G, *equal in Weight to an equal Bulk of the Fluid, be immerſed therein, it will take any Situation indifferently in any Part of the Fluid, as at* G, H, I, *without any Tendency to aſcend or deſcend therein:* For being totally immerſed, it muſt remove a Parcel of the Fluid of equal Bulk and Weight; and conſequently the Preſſure upwards is equal to the Tendency downwards on the lower Surface every where; and therefore it can have no Power to ſink: Alſo the Preſſure downwards muſt be equal to the Preſſure upwards on the upper Surface, whence it can have no Tendency to riſe or ſwim; it will therefore remain at Reſt in any Poſition, G, H, I, whereſoever in the Fluid. *Exp.* 162.

XVII. LASTLY, *If a Body* K *or* L, *heavier than an equal Bulk of the Fluid, be immerſed therein, it will deſcend by the Exceſs of its Gravity above that of the Fluid:* For, when immerſed, it will be reſiſted by the Force of an equal Bulk of the Fluid, which therefore will deſtroy juſt ſo much of the Gravity of the Solid; and conſequently, the Reſidue or Exceſs of Gravity in the Solid is that alone by which it muſt deſcend. *Exp.* 163.

FROM what has been premiſed of the Nature of Fluids, it will be eaſy to underſtand, *that the lighteſt Body* P *may be depreſs'd in the heavieſt Fluid*, by any Contrivance to keep the ſaid Fluid from preſſing on the under Surface of the light Body, by which means only light Bodies are made to ſwim. Thus *Cork* or *Wood* will abide at the Bottom of a Veſſel fill'd with Quickſilver. *Exp.* 164.

Exp. 165. AGAIN: *On the other hand, the heavieſt Body* M *may be made to ſwim in the lighteſt Fluid, by keeping the ſaid Fluid from preſſing on its upper Surface*, by means of the

Tube NO: For when by this means it is immerſed ſo deep as to keep off an equal Weight of the Fluid, the Preſſure then of the Fluid acting upon its under Surface upwards will be equal to the Weight of the Solid tending downwards; and therefore if the Solid be ſunk ever ſo little deeper, it muſt ſwim by the ſuperior Force or Preſſure of the Fluid upwards.

HENCE alſo the Reaſon of *trying the different Gravity*, *Denſity*, *or Strength* (as it is commonly call'd) *of divers Fluids or ſpirituous Liquors by the* HYDROMETER *or Water-Poiſe:* For, ſince the ſtronger any Fluid is, the greater will be its Reſiſtance to any Solid immerſed, 'tis evident the Hydrometer cannot ſink ſo far into the heavy or ſtrong Fluids, as into thoſe which are lighter or weaker. The ſeveral Degrees of Strength, therefore, are eaſily ſhewn by the graduated Neck of this Inſtrument. *Exp.* 166.

THE HYDROSTATIC-BALANCE is alſo an Inſtrument invented on the ſame Principle. By it *we have a moſt uſeful and ready Method of finding the various comparative or ſpecific Gravities of Fluids and ſolid Bodies, to the laſt Degree of Accuracy*; eſpecially in the *New Structure and Method of uſing it*, as repreſented in *Plate* III. *Fig*. XVIII. *Fig*.XVIII.

THE ſpecific Gravity of Fluids is readily determin'd by weighing one and the ſame ſolid Body in them ſeverally; for ſince we ſuppoſe the Balance *in Equilibrio* with the Body ſuſpended in the Air, the Equilibrium will be deſtroy'd when the Solid is immerſed in the Fluid, and muſt be then reſtored by Weights put into that Scale to which the Body is appended. Theſe Weights will ſeverally expreſs the Gravities of an equal Bulk of the reſpective Fluids; and conſequently, they may thus be compared with each other, or all of them with the Gravity of *common Water*, as uſual, and diſpoſed in a proper Table; making that of Water 1,000. *Exp.* 167.

Exp. 168. In the ſame manner, if divers Solids are firſt weigh'd in Air, and then afterwards immerſed in the ſame Fluid, as Water, for Inſtance, the *Equilibrium* will be deſtroy'd; which will be reſtored, as before, by putting in ſo much Weight as is equal to the Weight of the ſame Bulk of Water: The Gravity, therefore, of every Solid is thus compared with Water, and conſequently with each other; as in the following Table.

Exp. 169. THE *Application of Hydroſtatics* to the ſeveral Uſes of Life will be evident from the following Inſtances; having firſt premiſed, *that a Cubic Foot of common Water weighs very exactly* 1000 *Ounces Averdupois, or* 62 *Pounds and a half*; which may be reduced to *Troy* Weight, by conſidering, that the *Averd.* Pound is to the *Troy* Pound as 17 to 14, and the *Averd.* Ounce to the *Troy* Ounce as 51 to 56.

Exp. 170. HENCE, *to find the Quantity of Preſſure againſt the Sluice or Bank that pens the Water*, we have this Rule: *Multiply the Area of the Sluice under Water by the Depth of the Center of Gravity in Feet, and that Product again by* $62\frac{1}{2}$; *the Product will be the Number of Pounds required. Example:* Admit the Length of the Sluice be 20 Feet, the Depth of Water 5; then will the Area under Water be 100 Square Feet; which multiplied by $2\frac{1}{2}$, the Depth of the Center of Gravity, gives 250 Cubic Feet; which again multiplied by $62\frac{1}{2}$, gives 15625 *lb.* equal to 7 Tons nearly.

Exp. 171. AGAIN: *Since the Weight of Bodies is always as the ſpecific Gravity in equal Bulks,* it follows, that the Numbers in the following Table do alſo expreſs the Number of *Averdupois* Ounces contain'd in a Cubic Foot of each reſpective Sort of Matter therein mention'd. Therefore, *if the Magnitude of any Body be multiplied by the ſpecific Gravity, the Product will be its abſolute Weight.* Thus, ſuppoſe I would know what Weight of Lead will cover a Church whoſe Area is

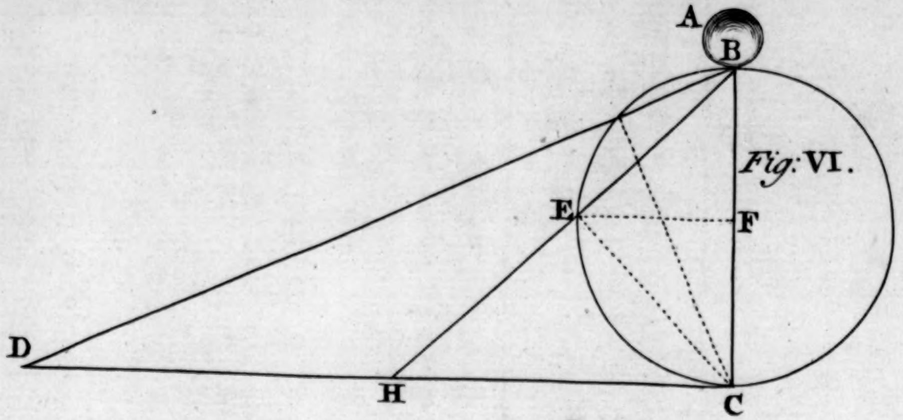


Fig: VI.

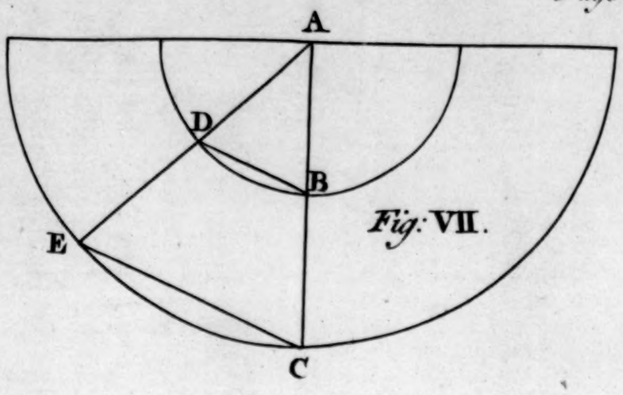


Fig: VII.

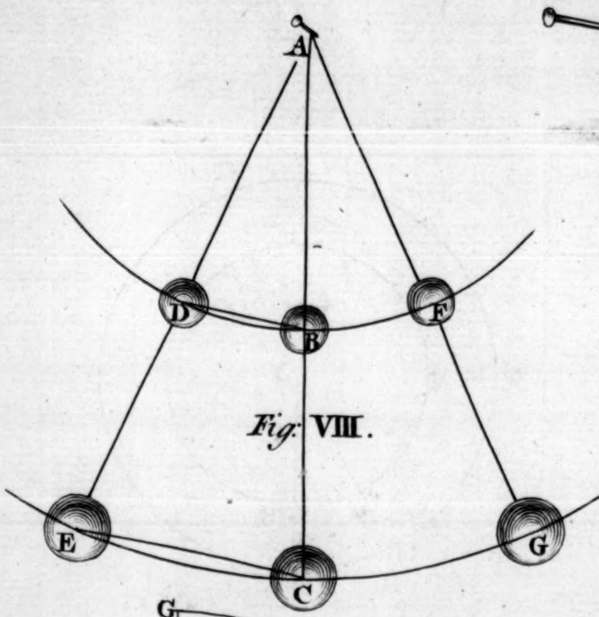


Fig: VIII.

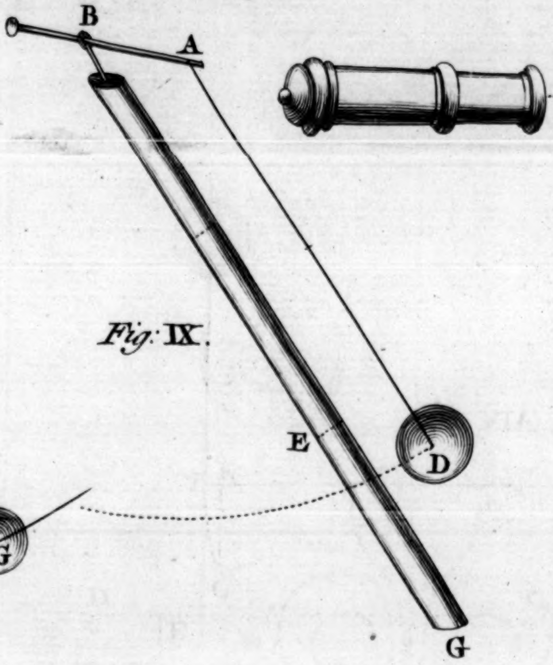


Fig: IX.

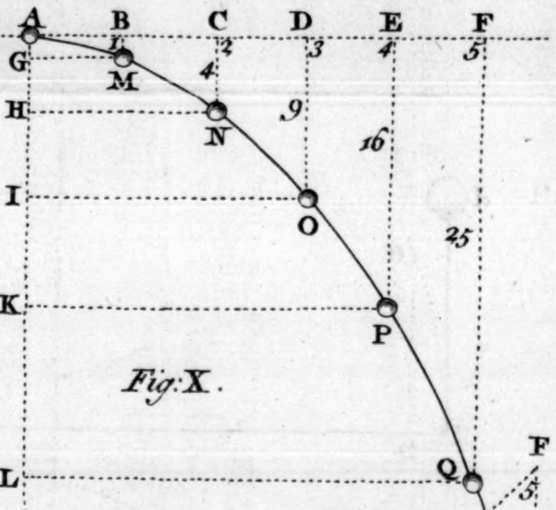


Fig: X.

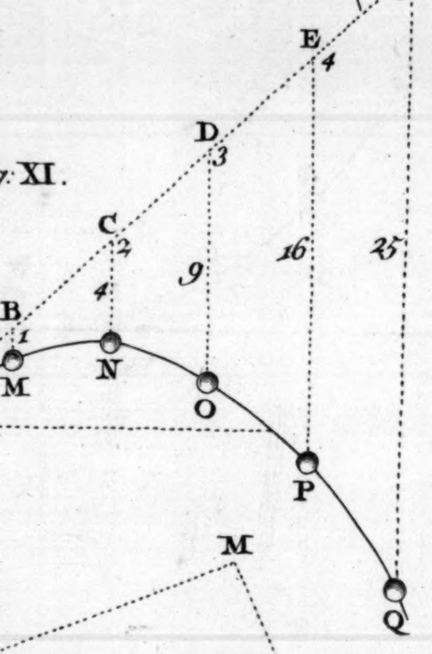


Fig: XI.

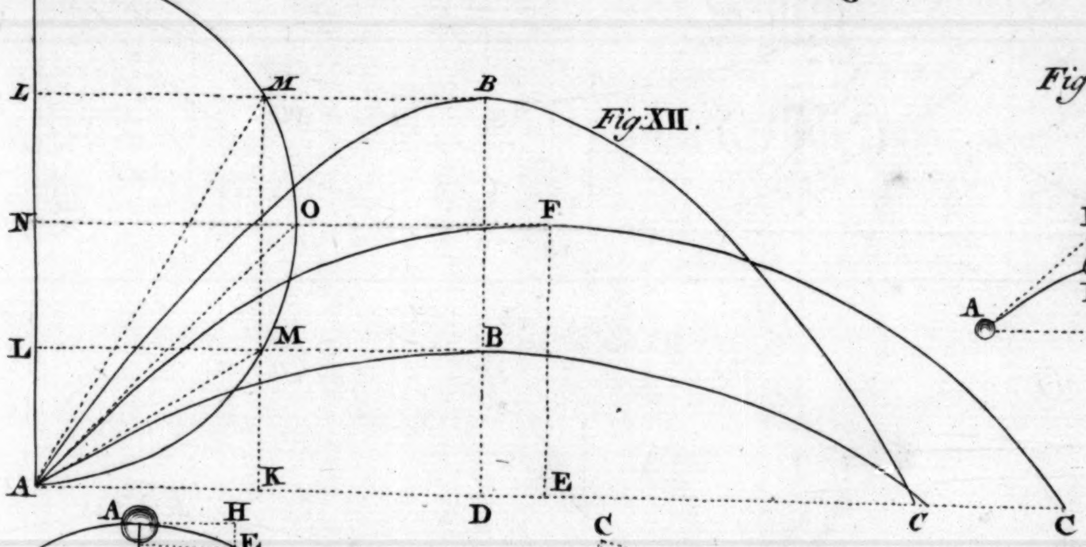


Fig: XII.

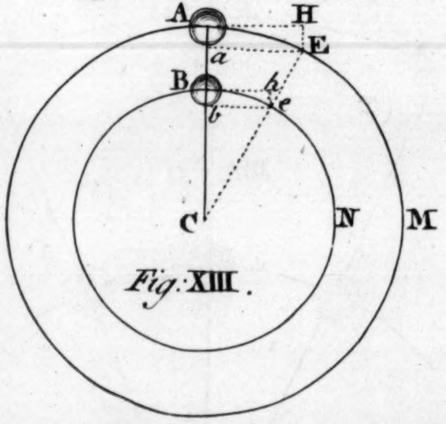


Fig: XIII.

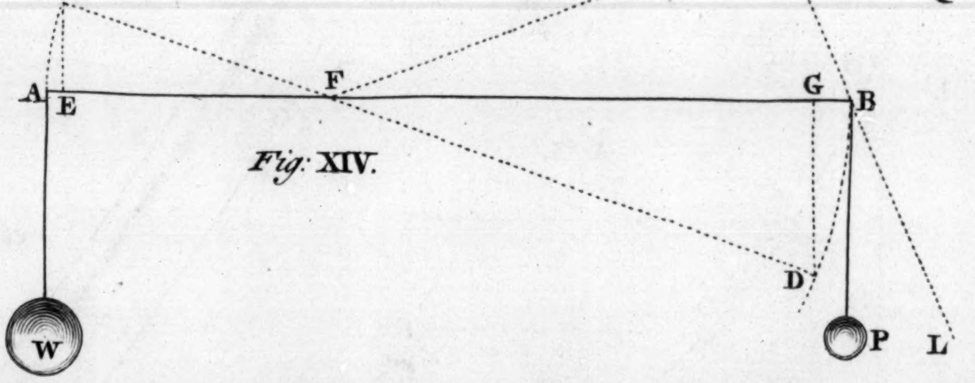


Fig: XIV.

E. Bowen sc.

30000 Feet, and the Thickneſs of the Lead $\frac{1}{100}$ of a Foot: Then *per* Rule, ($30000 \times \frac{1}{100} =$) $300 \times 11325 = 339750$ Ounces, or $97\frac{4}{5}$ Tons; the Weight required. Another uſeful Problem is, to *find the Magnitude of any Thing, when the Weight is known*; which is done, *by dividing the Weight by the ſpecific Gravity in the Table, the Quotient is the Magnitude* Exp. 172.
ſought. For Inſtance, What is the Magnitude of ſeveral Fragments of *Coral* whoſe Weight is 7 Ounces? Divide 7 by the ſpecific Gravity 2690, the Quotient is $\frac{26}{10000}$ of a cubic Foot; then $\frac{26}{10000} \times 1728 = 4\frac{1}{2}$ Cubic Inches, very nearly, the Magnitude required.

ALSO, *by knowing the Magnitude and Weight, we can find the ſpecific Gravity, by dividing the Weight by the* Exp. 173.
Magnitude in Cubic Feet. Thus ſuppoſe a Piece of Marble contain 4 Cubic Feet, and weighs 603 *lb.* or 10800 Ounces; then $\frac{10800}{4} = 2700$, the ſpecific Gravity required, as *per* Table.

HAVING given the ſpecific Gravity of Gold to Silver as 19 to 11, and ſuppoſe any Compound thereof, as Exp. 174.
King Hiero's Crown, whoſe ſpecific Gravity is 16; to determine the Proportion and Weight of the Gold and Silver employ'd in making it, ſay, *As the Difference of the ſpecific Gravities of the Compound and the lighter Ingredient*, viz. 5, *is to the Difference of the ſpecific Gravities of the heavier Ingredient and the Compound*, viz. 3, *ſo is the Bulk of Gold to that of Silver made uſe of.* That is, if the whole Crown were divided into 8 Parts, the Gold would conſiſt of 5, and the Silver of 3: Then the Magnitudes 5 and 3, multiplied by the ſpecific Gravities 19 and 11 ſeverally, will give the Numbers 95 and 33, which expreſs the *Proportion of the Weight of the Gold to that of the Silver.*

SINCE Bodies of different ſpecific Gravities, equiponderating each other in Air, upon being immerſed into Exp. 175.
Water, will have the *Equilibrium* immediately deſtroy'd by the greater

greater Reſiſtance of the Fluid, and conſequently the greater Loſs of Weight in the lighteſt and moſt bulky Body; therefore it follows, that in *buying Gold*, which is *heavier than Braſs*, we ſhould chuſe the *lighteſt Air*, *i. e.* when the Mercury in the Barometer ſtands loweſt; but in *buying Precious Stones*, *Pearls*, &c. which are *lighter than Braſs*, the beſt Time to do it in is *when the Air is heavieſt* and *moſt buoyant*, *viz.* when the Quickſilver ſtands higheſt in the Barometer: But in *ſelling Gold or Jewels*, the contrary Rules are to be obſerved in regard to the Gravity of the Air.

ONCE more: Since *the Goodneſs of Mineral Waters*, *Drugs*, *Metals*, *precious Stones*, &c. *is beſt ſhewn by their ſpecific Gravity*, it will at once appear of what vaſt Importance the Hydroſtatic Balance is, and how abſolutely neceſſary in the Hands of every judicious Dealer in any ſuch kind of Commodities.

Fig. XVIII.

I HAVE thought it expedient the Reader ſhould be acquainted with the Form and Manner of uſing ſo curious and valuable an Inſtrument, as here improved and repreſented in *Fig.* XVIII. The Parts of which are AB, the Foot on which it ſtands; CD, a Pillar ſupporting a moveable Braſs Plate EF, faſten'd thereto by the Screw in the Knob *e*. In the End of this Plate is fix'd an upright Piece IK, ſupporting another Plate GH, which ſlides backwards and forwards thereon, and is moveable every way about it. In the End of this Plate, at H, is fix'd (by a Nut beneath) a Wire LM, tap'd with a fine Thread from one End to the other; upon this moves the *Swan-Neck Slip* of Braſs NO, to which a very exact Balance is hung at the Point N; to one of whoſe Scales P is appended the heavy Body R, by a fine Horſe-hair or Piece of Silk S: The Weight of the ſaid Body R in the Air is expreſs'd by the Weights put into the Scale Q to make an *Equilibrium* therewith, which being deſtroy'd by immerſing the Solid in the Fluid TV, contain'd in the Glaſs WV, is again reſtored by Weights put into the Scale P. *So that the*

Weights in the Scale Q *compared with thoſe in the Scale* P, *ſhew at once the ſpecific Gravity of the Solid* R *to that of the Fluid* TV.

BY this means a Table of *Specific Gravities* for all Sorts of Solids and Fluids may be compoſed, in manner of the Specimen following:

Fine Gold, — — — —	19,640	Glaſs, — — — —	3,150
Standard Gold, — — — —	18,888	Marble, — — — —	2,700
Mercury, — — —	14,000	Coral, — — — —	2,690
Lead, — — — —	11,325	Stone, — — — —	2,500
Fine Silver, — — —	11,091	Bone, — — — —	2,000
Standard ditto, — — — —	10,535	Ivory, — — — —	1,825
Copper, — — — —	9,000	Oil of Vitriol, — — —	1,700
Braſs, — — — —	8,000	Milk, — — — —	1,030
Iron, — — — —	7,645	Common Water, — — —	1,000
Tin, — — — —	7,320	Firr, — — — —	0,550
Diamond, — — —	3,400	Cork, — — — —	0,240

LECTURE V.

HYDRAULICS.

BY HYDRAULICS we are to underſtand the Science of the Motion of Fluids, and the Conſtruction of all Kinds of Inſtruments and Machines relating thereto; alſo the Nature of Springs, the Theory of the Tides, *&c.* are uſually explain'd under this Head.

THE *Motion of Fluids*, viz. their *Deſcent or Riſe* below or above the common Surface or Level of the Source or Fountain is cauſed either (1.) By the Natural Gravity or Preſſure of the Fluid contain'd in the Reſervoir or Fountain; or (2.) By the Preſſure or Weight of the Air on the Surface of the Fluid in the Reſervoir, when it is at the ſame time either taken off, or diminiſhed, on ſome Part in Aqueducts, or Pipes of Conduit. (3.) By the Spring or elaſtic Power of compreſſed or condenſed Air, as in the common Water-Engine. (4.) By the Force or Preſſure of Piſtons, as in all Kinds of forcing Pumps, *&c.* (5.) By the Power of Attraction, as in the Caſe of Tides, *&c.* Of all which in Order.

I. THE moſt natural Motion of Fluids is that ariſing from the Force of their own Gravity, by which thoſe Parts which ſtand higheſt preſs upon others below them, till by that means they riſe to the ſame horizontal Level. Thus Water in a Fountain A B C D by its Preſſure raiſes that in the Aqueduct F G H to the ſame Height I K L M, in every Direction or Poſition of the Duct G H or G N; unleſs the Orifice of the ſaid Duct be below that Level, in which Caſe the Water will continually flow from the ſame. The Reaſon hereof is evident from the Principles of *Hydroſtatics*, where it was ſhewn, *that the Preſſure of Fluids was in proportion to the Altitude only, and not according to the Quantity thereof*; and therefore the Effect or Riſe of the Fluid in the Duct muſt be equal thereto. Or thus; *The Velocity of the Fluid in the Duct at* L, *is to that in the Fountain at* I K, *as the Quantity of the Fluid in the Fountain is to that in the Duct*; whence (from the Principles of *Mechanics*) the *Momentum* of the Fluid in each will be equal, and conſequently an *Equilibrium* will enſue at equal Altitudes K and L in both.

Exp. 176.

Fig. XIX.

HENCE we have Conduits often ſupplied with Water from Springs which lie above them; and Cocks to ſupply the Inhabitants of a Town with Water by Pipes of Conduit proceeding from a Reſervoir in a Situation above the higheſt Part of the Town.

HENCE alſo the Deſcent of Water in Rivers, Streams, and Canals, from Springs and Sources above the common Surface of the Earth; and the Breaking out of Springs at the Bottoms and on the Side of Hills, from Ciſterns and Reſervoirs in the internal Parts above them, which receive their Waters from *Rain*, *Dew*, *condenſed*

denſed Vapours, *melted Snow*, &c. diſtilling or percolated through the Pores or Crevices and Chaſms of the upper Part of the Earth.

By the Preſſure of the Fluid it may eaſily be convey'd over Vallies and Hills by bended Pipes or Syphons, *Exp.* 177. from Ponds or Reſervoirs in a higher Situation; which the Ancients being ignorant of, were at vaſt Pains and Expence very often to effect. Hence the running of Water through the *bended Syphon* accounts for the odd Phænomena of *intermitting and reciprocating Springs*; and alſo in that Inſtrument call'd the *Tantalus-Cup*; as will be evident from *Exp.* 178. Experiment. The Riſe of Water in Wells alſo is owing to the Weight of that in the ſubterranean Ciſterns from whence they are ſnpplied by proper Canals or Springs.

From the Preſſure of the ſuperior Fluid we have the Invention of a *Natural Fountain*, which playing from *Exp.* 179. the ſmall Orifice of an Adjutage at the Bottom, will ſpout very beautifully nearly to the Height of the Water from the Fountain; but it cannot quite reach that Altitude, by reaſon of the Air's Reſiſtance.

From this Preſſure of Fluids, as the Cauſe, we can eſtimate the various *Momenta* or Forces of ſeveral Jets ſpouting through the Sides or Bottoms of Veſſels at different Depths below the Surface: For the *Momenta* of Fluids, as well as ſolid Bodies, is *compounded of the Quantity of Matter and Velocity*; but in ſpouting Fluids, *the Quantity of the Fluid iſſuing through the ſame Hole in the ſame Time is always as the Celerity of its Motion*, as is eaſy to conceive: Whence the *Momenta of ſpouting Fluids are proportional to the Squares of the Velocities, or Quantities of Matter iſſuing out in a given Time:* But ſince the *Momenta* are the Effect of Preſſure, it is evident, *the Velocity, or Quantity of ſpouting Fluids is ever proportional to the Square Root of the Preſſure or Altitude of the Fluid.*

FROM hence it appears, *that the Velocity of a Fluid ſpouting at any Depth below the Surface, is equal to the Velocity a heavy Body would acquire by falling from the ſame Height*; becauſe that Velocity, as was obſerved, is always as the Square Root of the Space deſcended through. If therefore on the Altitude of the Fluid A K, as a Diameter, we deſcribe the Semicircle A F K; and from any Point therein, as I, we draw the Perpendicular I H, that ſhall be proportional to the Diſtance to which the Fluid will ſpout from an Adjutage at H: For the *Velocity* will be as the Square Root of A H, and the *Time* as the Square Root of H K; whence the Product of theſe two will expreſs both the Space paſs'd over by the projected Body, and alſo the Line H I, as is well known to Geometers. *Fig.* XX.

HENCE it follows, that *a Fluid will ſpout from a Hole or Adjutage* D *in the Center of the Semicircle, or middle Point of the Altitude* A K, *to the greateſt Horizontal Diſtance* K M *poſſible*; becauſe the Perpendicular F D is the greateſt that can be drawn to the Diameter A K. Alſo 'tis evident, that *from two Holes* B *and* H, *equally diſtant above and below the middle Altitude* D, *the Jets of Water will be made to the ſame horizontal Diſtance* K N; becauſe the Perpendiculars to theſe two Points, *viz.* C B and I H, are equal.

Exp. 180. MOREOVER, the horizontal Diſtance K M, to which the Water ſpouts from D the Center, is equal to the Diameter or Altitude A K, or twice D F. For ſince the Velocity of the Jet at O is equal to that acquired by falling thro' the Height A D, or D K, it will, as being uniform, carry the Fluid in an horizontal Direction over twice the Space D K or D F in the ſame Time: And therefore, ſince the Diſtances of Jets from D and B are as D F to B C, and the Diſtance of the Jet from D is equal to twice D F, the Diſtance of the Jet from B will be alſo equal to twice B C, or K N = 2 B C.

I SHALL only obſerve farther in regard to ſpouting Water, that the Jet will go farther through the bare *Exp.* 181. Hole in the Veſſel at P, Q, or R, than through the Adjutage PB inſerted in thoſe Holes, and farther ſtill in proportion as the Adjutage is ſhorter and the Bore larger. On the contrary, if a Pipe be inſerted perpendicularly into the *Exp.* 182. Bottom of a Veſſel, it will diſcharge itſelf ſooner thro' it, than thro' the bare Hole; and ſtill quicker as the Pipe is longer and larger.

II. THE ſecond Cauſe of the Riſe or Motion of Fluids is the *Preſſure of the Air* on the Surface of that in the Fountain or Reſervoir. Thus if a SYPHON or *Crane* be im- *Exp.* 183. 184. merſed with the ſhorter Leg in Water, and the Air ſuck'd out of the Inſtrument, the Fluid will aſcend into the vacuous Space by the Preſſure of the Air on the Water in the Veſſel, and fill the whole Cavity of the Tube; and becauſe there is a greater Column or Body of Water in the longeſt Leg, it will preponderate and deſcend through it; and thus keep flowing out, till the Veſſel is exhauſted to the Orifice of the ſhorter Leg.

THE Effect of the COMMON PUMP is from the ſame Principle: For the Bucket or Sucker, raiſing a Column *Exp.* 185. of Water above it in the Barrel, makes a vacuous Space, or greatly attenuates the Air in the Barrel and Pipe below it; whence the Water muſt neceſſarily riſe in the Pipe, by the ſuperior Preſſure of the Air on the Surface of that in the Well. The Water aſcending in the Pipe, paſſes through the Valve in the Bottom of the Barrel, which ſhutting upon the Depreſſion of the Sucker, the Water is thereby forced through the Valve of the Sucker into the Ciſtern of the Pump, and diſcharged through the Spout. All which is clearly ſhewn by the Model of a Pump in Glaſs.

III. IV. BUT the moſt conſiderable of all Water-Engines is that call'd *Newſham*'s FIRE-ENGINE, from the great Improvements which Mr. *Newſham* made in it; the Nature and Effect of which will be eaſily underſtood from a perpendicular Section of a Model, with ſome Variation which I have made in the Structure thereof. The Motion of the Water in this Engine is effected by the *Preſſure of the Atmoſphere*, *by the Force of Piſtons*, and *by the Spring of condenſed Air*, in the following Manner, *viz.* When the Piſton R is raiſed, a *Vacuum* would be made in the Barrel TV, did not the Water follow it from the inferior Canal EM (through the Valve H) which riſes through the Glaſs Tube EF immerſed in the Water of a Veſſel by the Preſſure of the Atmoſphere on the Surface thereof. The Water of the Barrel TV, by the Depreſſion of the Piſton R is forced through the ſuperior Canal ON, to enter by the Valve I into the Air-Veſſel *abcd*; and the like being done alternately by the other Barrel WX, and its Piſton S, the Air-Veſſel is by this means continually filling with Water, which greatly compreſſes the Air above the Surface of the Water in the Veſſel, and thereby proportionably augments its Spring; which at length is ſo far increaſed, as to re-act with great Force on the Surface Y of the ſubjacent Water; which aſcending through the ſmall Tube *ef* to the *Stop-Cock eg*, is there, upon turning the Cock, ſuffered to paſs through a Pipe *h*, fixed to a *Ball and Socket*, from the Orifice of which it iſſues with a great Velocity, to a very great Height or Diſtance, in a ſmall continued Stream, directed every way, or to any particular Place, by means of the Ball and Socket.

Fig. XXI.

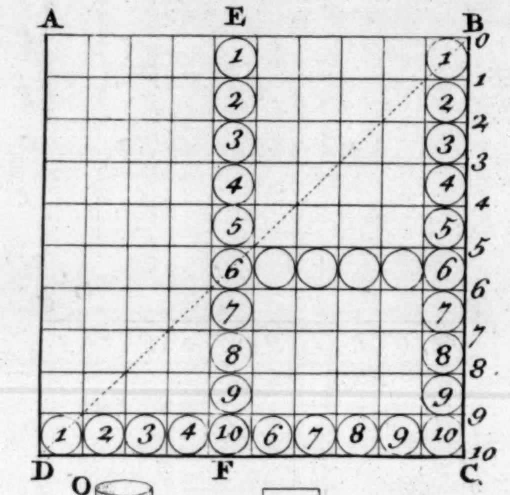
Exp. 186.

THERE is another Sort of *Fire-Engine*, which works by Fire, in the following Manner. ABC is a Copper-Veſſel, partly fill'd with Water to DE, which being ſet over a Fire, and made to boil, will fill the upper Part DBE with a vaſtly elaſtic Vapour, the ſufficient Strength whereof is known by its forcing open a ſnifting Valve at *e*: This heated elaſtic Steam is, by turning a Cock at F, let into

Fig. XXII.

Exp. 187.

THE NEW HYDROSTATIC BALLANCE



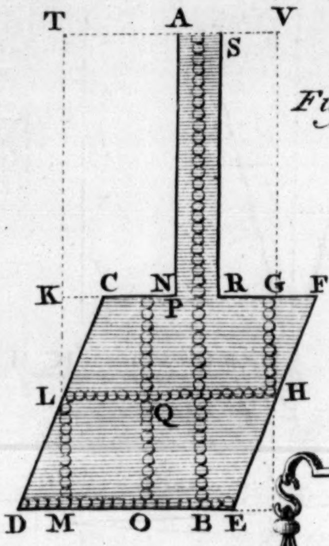


Fig: XVI.

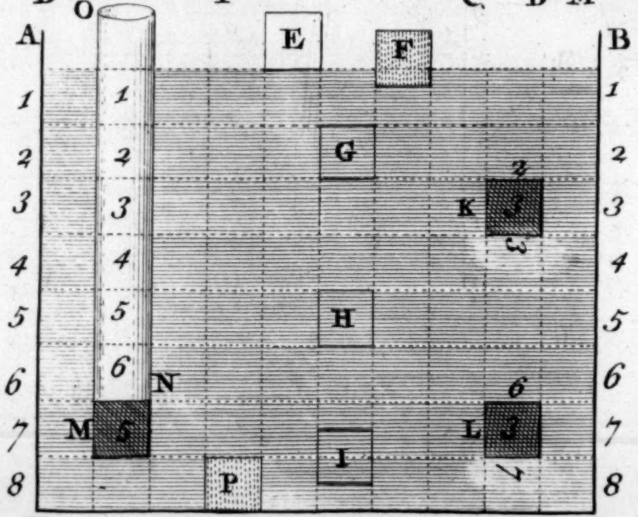


Fig: XVII.

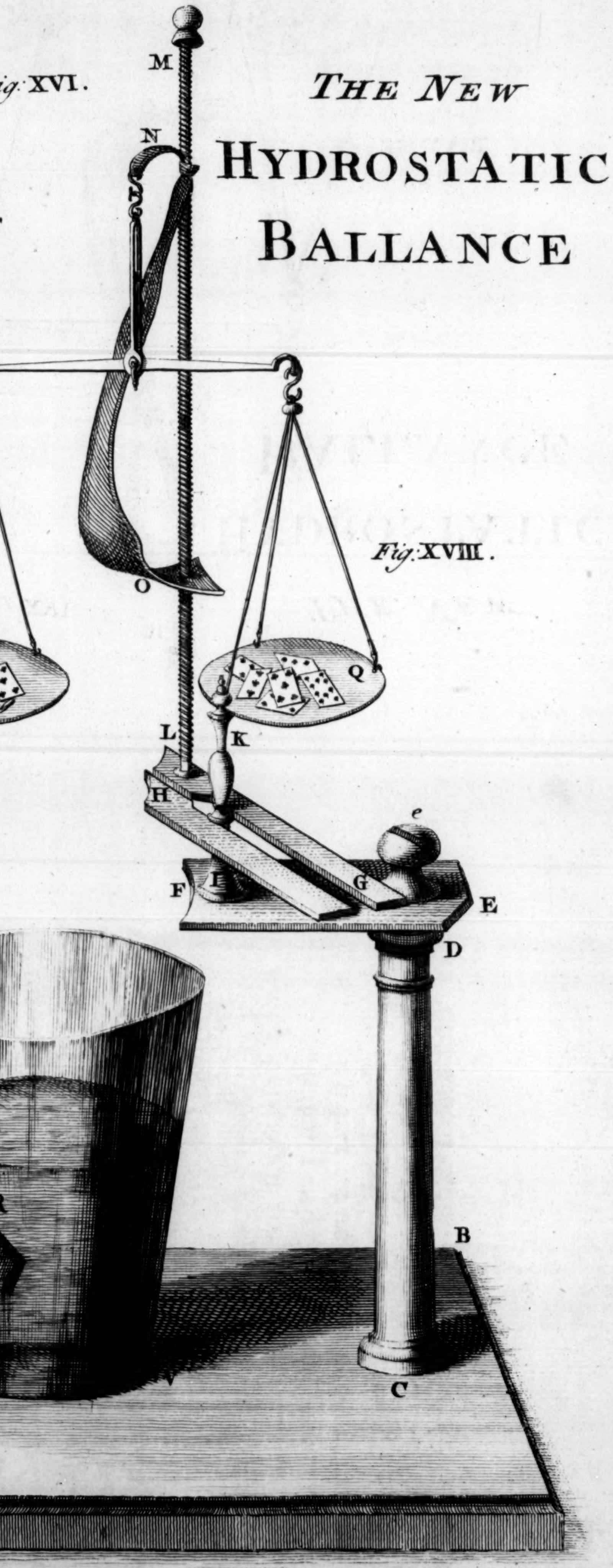


Fig: XVIII.

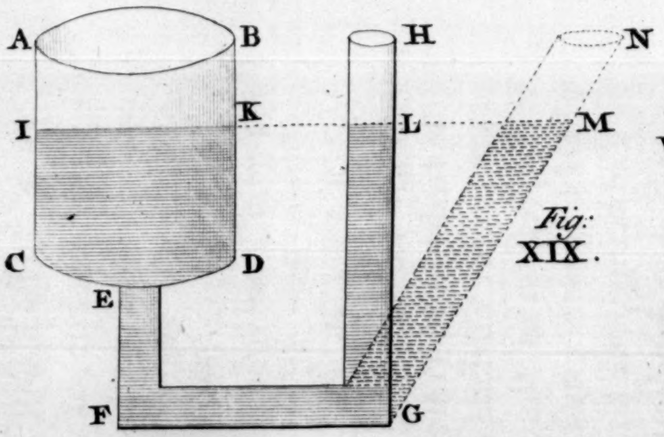


Fig: XIX.

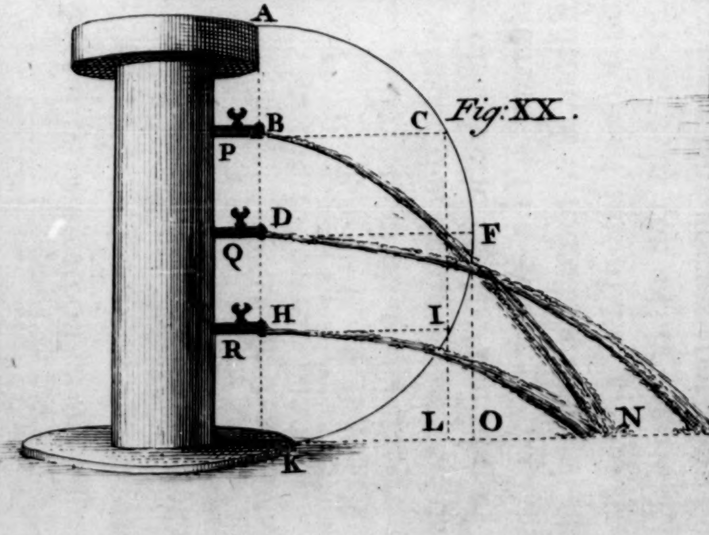


Fig: XX.

E: Bowen sc.

into the Barrel *a b c d*, where by its elaſtic Force it raiſes the Piſton G, which drives the Air above it through a proper Clack at the Top. After this, that the Piſton may by its Weight deſcend, a little cold Water from the Fountain *f g h i*, is let in at the Bottom by turning a Cock at *k*, which, in Form of a Jet, condenſes the hot Steam in the Barrel into 13000 times leſs Space than before it took up, which makes a ſufficient *Vacuum* for the Piſton to deſcend in. The Piſton G, and Lever H I, being thus put into Motion, do accordingly raiſe and depreſs the Piſton K in the Barrel of the forcing Pump L M on the other Side; which, by the Pipe N, draws the Water from the Depth W, and forces it to riſe and ſpout through the Tube O, continued to any Height at pleaſure. This Engine is uſed to draw the Water from Coal-Pits and other Mines. Beſides theſe, there are various other Water-Engines of a more complex Structure; but as they all act on the ſame Principles with theſe two deſcribed, 'tis needleſs to ſay any thing of them here.

THE above-mention'd *prodigious Rarefaction* of a ſmall Quantity of Water will be made very ſenſible by *Exp.* 188. the *Æolipile*, whoſe Nature and Uſe in the Production of *a continual and moſt powerful Blaſt of Steam*, or *vapourous Wind*, is a *Phænomenon* equally curious and ſurpriſing, as will appear from the Experiment.

V. THE laſt Cauſe of the Motion of Fluids which I mention'd was that of *Attraction*. We have already ſeen how by this means any Fluid will aſcend above the common Surface in *Capillary Tubes*, &c. I ſhall only take notice here, that the *Capillary Syphon*, which, by the ſole Power of *Attraction*, will exhauſt a Veſſel of its contain'd Fluid, is a Curioſity which few have ſeen, and none can ſufficiently admire.

BUT the moſt notable and obvious Motion of Fluids ariſing from Attraction, is that of the Tides; the Waters of the immenſe Ocean, forgetful, as it were, of their natural *Quietus*, inceſſantly move, and roll in ſwelling Tides obſequious to the ſovereign Power of the Moon, and weaker Influence of the Sun.

To illuſtrate this, let N E S Q repreſent the Earth, covered over with Water A B D F; N S the Axis of the Earth, E Q the Equator, T R the Tropic of *Cancer*, *t r* the Tropic of *Capricorn*, M the Moon in her Orbit, S the Sun in his. Now ſince all Bodies are endued with an attracting Virtue, the Moon will attract all the Water in the neareſt Hemiſphere F A B, with Degrees of Force which are inverſely as the Squares of the Diſtances from all Parts; and therefore with the ſtrongeſt Force where the Diſtance is leaſt, *viz.* in the Point A directly under her; and this Attraction being in this Hemiſphere contrary to that of the Earth, the Water in all Parts from B and F towards A will have their Gravity gradually decreaſing, and be lighteſt of all at the Part A; and conſequently muſt there ſtand higher than at the Point F, where they are more attracted by the Earth, and ſo heavier, as is evident from the Laws of *Hydroſtatics*. *Fig.* XXIII.

AGAIN: In the other Hemiſphere F D B, the Attraction of the Moon conſpires with that of the Earth; but decreaſing as the Squares of the Diſtances increaſe, the joint Force of Attraction will every where decreaſe from F and B toward D, the Point oppoſite to the Moon; where, again, the Waters will be lighteſt, and therefore ſtand higheſt to preſerve the *Equilibrium*. Whence it appears, that by this Sum and Difference of the Moon's and Earth's Attraction, there will neceſſarily enſue a Protuberance or Swelling of the Waters, which we call *Tides of Flood*, in the two Points A and B directly under the Moon. Alſo in the two Points F and B, as the Waters are there moſt attracted, ſo they will be heavieſt, and conſequently riſe to the leaſt Height from the Earth's Surface, whence they are called *Tides of Ebb*, or the *Ebbing of the Water*.

IF to the Power of the Moon we add that of the Sun, we ſhall have the Tides conſiderably augmented at the *Conjunction* in S, or *Oppoſition* in H, that is, *at the New and Full Moons*, which are call'd *the Spring Tides*; as thoſe which happen when the Sun is at O or P are call'd *Neap Tides*, the Waters at A and D being then loweſt, becauſe the Attraction of the Moon is then in ſome meaſure counter-acted by that of the Sun. The Power of the Moon to diſturb the Waters is to that of the Sun as 51 to 10 very nearly: whence the Power producing *the Spring Tides* is that which cauſes *the Neap Tides*, as *the Sum of thoſe Numbers to their Difference*, or as 61 to 41, that is, as 3 to 2.

IF the New or Full Moon happen in the *Equinoctial*, the Tides will be *the greateſt poſſible*; becauſe there the *Gravity* of the Waters is more than at any other Place diminiſh'd by the *centrifugal Force* of the *diurnal Rotation:* Conſequently, all the Cauſes there conſpire to render the Waters *lighter*, or *raiſe them higheſt in Tides*; eſpecially if *the Moon be then neareſt the Earth*, and *the Earth neareſt the Sun*, as in *December* it is.

IT is farther to be obſerved, That of *the two Tides of Flood* at A and D, that at A is greateſt to any Place T in *Northern Latitude*, when the Moon is in *Northern Signs*, and above the Horizon; for the Point A is then nearer the *Zenith* of the Place G, than the oppoſite Point D is to the ſame Place at R twelve Hours afterwards; and conſequently, the Height of the Tide T G is greater than that of the oppoſite Tide R *g*. The contrary happens when the Moon is in *Southern Signs*.

THAT there are *two Tides of Flood*, and *two of Ebb*, ſucceeding each other *alternately at the Interval of ſix Hours*, is obvious from the *Figure*. That they happen *later each Day near an Hour*, is owing to their exact Correſpondence to the *Motion of the Moon*, which daily *culminates* ſo much later. That they happen *not when the Moon is in the Meridian*, *but about three Hours after*, is owing to the Force of the Moon being then greater than when in the Meridian of any Place; as the Heat of the Day is greater at Three o'Clock than at Twelve; and the Heat of the Summer is greater in *Auguſt*, than at the 10*th* of *June*. Laſtly, *that the greateſt Spring Tides happen not at the* 10*th of* March, *and* 12*th of* September, *but in* February *and* October, is becauſe the Sun being neareſt the Earth in *December*, his Influence is then ſtrongeſt, and ſo muſt quicken the Time of the greateſt *Vernal Tides*; and being weakeſt in *June*, the Time of the *Autumnal Tides* will neceſſarily be retarded.

SUCH are the *Phænomena* of the *Tides*, according to a general Theory, and are found to be verified in thoſe Parts of the Earth's Surface which are *wholly cover'd with Water*, as the Theory requires; I mean, the vaſt *Atlantic and Weſtern Oceans*.

LECTURE VI.

PNEUMATICS.

THAT Part of *Natural Philoſophy* which treats of the *Nature*, *Properties*, *and Effects of the* ATMOSPHERE, or *Body of Air* encompaſſing the *Earth*, is call'd PNEUMATICS, from the *Greek* Word for *Wind* or *Breath*.

THE *Air* is generally eſteemed a *Fluid*, but yet differs from the general Nature of Fluids in two Particulars, *viz.* (1.) In that it is *compreſſible*, which Property no other Fluid has; and (2.) It cannot be *congeal'd*, or any how *fixed*, as all other Fluids may. It muſt therefore be eſteem'd a Fluid *ſui generis*, if it can with Propriety be call'd a Fluid at all.

THAT the Air was created at firſt with the Earth itſelf, is not to be doubted; and that ever ſince there has been a *conſtant Generation* of Particles of Air by the mutual Action of Bodies upon each other, as in *Fermentations*, and all Kinds of *natural and artificial Chemiſtry*, Sir *Iſaac Newton* thinks very reaſonable to ſuppoſe; and Mr. *Boyle* has given numerous Experiments relating to the Production of *artificial* or *factitious Air*.

THAT the Air is a *heavy or ponderous Body*, muſt follow from the Nature of the Matter of which it doth conſiſt; and ſince thoſe Particles ariſe from Bodies of every Kind in or upon the Earth, 'tis evident the conſtituent Parts of Air are of a moſt *heterogeneous Nature*, and infinitely various in their ſpecific Gravities: Whence alſo it will follow, that as the Matter which compoſes the Body of Air, or Atmoſphere, is *always variable*, ſo will its Weight or Gravity be likewiſe; as we conſtantly experience by the BAROMETER, of various Kinds and Structure. *Exp.* 189.

SINCE the Particles of Air are ſuch as being ſeparated from Bodies beyond the Sphere of corpuſcular Attraction, are ſtrongly repell'd from thoſe Bodies; which Repellency being mutual between the Particles, they do by this means conſtantly repel each other, and therefore they muſt obſerve a mutual Diſtance equal to the Diameter of the Sphere of this their repulſive Power: If therefore thoſe aerial Particles ſhould be obliged by any impreſs'd Force to approach nearer to each other than the ſaid Diſtance, the *repulſive Power* will re-act or reſiſt the ſaid Force with an equal *Momentum*; and thus cauſe what we call the RENITENCY, ELASTICITY, or SPRING of the Air; which is ſo ſenſible by the common Experiment of a *blown Bladder*, and many others on the *Air-Pump*. *Exp.* 190.

BY reaſon of the *Spring of the Air*, its DENSITY muſt be always different in different Altitudes from the Earth's Surface; for the lower Parts of the Air, being preſſed by the Weight of the ſuperior Parts, will be made to accede nearer to each other, and the more ſo as the Weight of the incumbent Air is greater; and hence we ſee the *Denſity* of the Air is greateſt at the Earth's Surface; and decreaſes upwards in *geometrical Proportion* to the Altitudes taken in *arithmetical Progreſſion.* Now it is found that the Air is four Times more rare at the Height of ſeven Miles than at the Earth's Surface; and therefore at the Altitudes of 7. 14. 21. 28. 35. 42. 49. the Rarity of the Air will be 4. 16. 64. 256. 1204. 4096. 16384.

If the Air were of an equal Denſity throughout, *Exp.* 191. the Height of the Atmoſphere might be determined; for by Experiment we find the Length of a Column of Air 72 Feet high is equal in Weight to *one Inch* of Water of the ſame Baſe: Hence the Denſity of Air is to that of Water as 1 to 864. It is alſo found by Experiment, that the Weight of a Column of Air the Height of the Atmoſphere will be equal to the Weight of a Column of Water of the ſame Baſe, and 32 Feet, or 384 Inches high: Wherefore 864 multiplied by 384 will produce 331776 Inches, or a little above 5 Miles, for the Height of the Atmoſphere, were the Denſity every where the ſame as at the Earth.

But ſince the Denſity of the Air decreaſes with the Preſſure, it will be more rarefied and expanded the higher we go; and by this means the Altitude of the Atmoſphere becomes indefinite, and terminates in pure *Æther*. But though we cannot aſſign the real Altitude of the Atmoſphere, it is certain from Ob- *Exp.* 192. ſervation and Experiment, that 45 or 50 Miles is the utmoſt Height where the *Denſity is ſufficient to refract a Ray of Light*; and therefore that may be eſteem'd the Altitude of the Air to the leaſt ſenſible Degree of Denſity.

Since the Gravity of the Air is ſo various, that at *Exp.* 193. one time it will ſuſtain a Pillar of Mercury 31 Inches high, when at another it will raiſe it but to the Height

of 28 Inches, in the *Barometer*; it follows, that we may take $29\frac{1}{2}$ Inches of Mercury for the *mean Altitude*, and conſequently its Weight for the *mean Weight* of a Pillar of Air of the ſame Baſe. But a Column of Mercury whoſe Baſe is *one Square Inch*, and Altitude $29\frac{1}{2}$, weighs about $17\frac{1}{2}$ *lb.* which is equal
to the Preſſure of Air on every *Square Inch*; and therefore Exp. 194.
upon every *Square Foot* it will be 2520 *lb.*; and allowing $14\frac{1}{2}$ *Square Feet* for the Surface of the Body of a middle-ſized Man, it muſt ſuſtain a Preſſure of 36540 Pounds, or $16\frac{3}{10}$ Tons, when the Air is at a mean Gravity. This prodigious Force would cruſh us within the Compaſs of a Pepper-Corn, were it not that it is equal on every Part, and counter-balanced by the equal Re-action of the Spring of the Air within us.

THE Weight of the Air is proved by a great Variety of curious Experiments, the principal of which here follow.
(1.) By actually *weighing it in a nice Balance*; where Exp. 195.
we ſhall ſee that *one Gallon of Air* will weigh a *Dram*
very nearly. (2.) By filling a Glaſs Tube with Mercury, 196.
and inverting it in a Baſon of the ſame Fluid, where it will appear that a Column will be ſupported in the Tube by the ſole Weight or Preſſure of the Air, to upwards
the Height of 28 Inches. (3.) By taking the Air off Exp. 197.
from the Surface of the Quickſilver in the Gage of the Air-Pump, which then immediately riſes by the Preſ-
ſure of the external Air. (4.) By exhauſting a Re- 198.
ceiver placed over the Hole of the Braſs Plate on the Pump, which will then be kept faſt on by the Preſſure
of the incumbent Air. Or, (5.) More demonſtratively 199.
by exhauſting a ſmall Receiver under one larger, and letting in the Air at once upon it; which will then be faſten'd to the Plate, as before, though not placed over the
Hole. (6.) By placing the Hand on the open Re- Exp. 200.
ceiver, and exhauſting, the Weight of the Air on the

Hand will be extremely ſenſible. (7.) By placing a
Exp. 201. plain Piece of Glaſs on the ſaid open Receiver, which,
when the Air is a little exhauſted, will be broke into Pieces by
the Weight of the Air. (8.) A Bladder tied over the
Exp. 202. ſame Glaſs will be broke in the ſame manner. (9.) The
203. Air exhauſted from a thin Bottle under a Receiver, and
then ſuddenly let in, will, by its Weight, inſtantly re-
204. duce it to very ſmall Pieces. (10.) A Bottle broke by
205. the ſame means another way. (11.) By putting a Piece
of Wood under Quickſilver in the Receiver, and then
exhauſting the Air, and letting it in again, it will by its Weight
force the Quickſilver into the Pores of the Wood, and
Exp. 206. very ſenſibly increaſe its Weight. (12.) The exhauſted
Braſs Hemiſpheres prove not only the prodigious Weight
of the Air, but alſo the Quantity thereof very exactly.
207. (13.) By exhauſting Glaſs Bubbles ſwimming in Water,
and letting the Air in again, it will force the Water
208. into the Bubbles, and make them ſink. (14.) The Sy-
ringe with its Weight deſcending *in Vacuo*, and aſcend-
ing again upon the Admiſſion of Air, does very prettily prove
the *Preſſure of the Air*, and the *Rationale* of Syringes in ge-
neral.

THAT Water riſes in *Pumps*, *Syphons*, and all Kinds of *Water-Engines*, by the *Preſſure of the Air* only, is made evi-
Exp. 209. dent by taking off the ſaid Preſſure (in the exhauſted
Receiver) from a Baſon of Mercury, which then will
not riſe in the Pipe of the Syringe on drawing up the Piſton, as it
will in the open Air.

THE SPRING *of the Air* is demonſtrable by various
Exp. 210. Experiments: As, (1.) By the great Expanſion of a
ſmall Quantity of Air in an emptied Bladder, when
the Air is taken off from the external Parts in the Re-
211. ceiver. (2.) By the Extruſion of a Fluid out of a Glaſs
Bubble,

Bubble, by the Expanſion of the Bubble of Air contain'd therein.
(3.) By the Expulſion of the White and Yolk of *Exp.* 212.
an Egg through a ſmall Hole in the little End, by the
Expanſion of the Air contained in the great End; and
alſo, (4.) By raiſing up the Skin of the Egg (after the 213.
Yolk is taken away, and one half of the Shell) by the
Expanſion of the ſaid included Bubble of Air, ſo as
almoſt to fill the Half-Shell. (5.) Glaſs Bubbles and 214.
Images fill'd with Water, ſo as to make them juſt ſink
in Water, will, upon exhauſting the Air from the Surface,
riſe to the Top of the Veſſel. (6.) Alſo a Bladder 215.
fill'd with Air, and juſt made to ſink with a Weight,
will, upon Exhauſtion, ſoon riſe by the Expanſion of
the contain'd Air. (7.) The Spring of the Air will 216.
ſhew itſelf alſo by raiſing heavy Weights laid on a
Bladder, half fill'd with Air, in a proper Veſſel under
the Receiver. (8.) Beer, Cyder, Water, and porous 217.
Bodies, do emit great Quantities of Air under the exhauſted
Receiver. (9.) Fiſhes are made ſo light or 218.
buoyant by increaſing the Spring of the Air in their
Bladders, upon Exhauſtion, that they riſe to the Top
of the Water, and cannot again deſcend to the Bottom.
(10.) Shrivel'd Apples are made to look fair and 219.
ſmooth by the Spring of the contain'd Air filling out
the Wrinkles. (11.) The Spring of the Air in a ſquare 220.
Bottle, cemented cloſe, will immediately burſt it in
pieces, upon exhauſting the incumbent Air. (12.) But 221.
that curious Experiment which ſhews the Force of the
Spring of the Air to be equal to its Weight or Preſſure, is by
raiſing the Mercury, by the Expanſion of a ſmall Quantity of
confined Air, to the ſame Height in an exhauſted Tube above the
Pump, as that which it is raiſed to in the Mercurial Gage by the
Preſſure of the Atmoſphere below it.

THE great Action of animal Life, *viz. Breathing*, by *Inſpiration*
and *Expiration* of Air, is owing to the *Preſſure*
Exp. 222. and *Spring* of the Air conjointly, as is evident by the
Contraction and *Expanſion* of a Bladder in a Bottle, under the *exhauſted Receiver*.

HENCE the Neceſſity of Air for *Reſpiration* and *animal*
Exp. 223. *Life* in moſt Sorts of Creatures, which die very
ſoon in the *exhauſted Receiver*: Though ſome Animals
224. will not be kill'd in this manner; as *Flies*, *Frogs*,
Toads, ſome ſort of *Fiſhes*, &c.

THAT Air paſſing through the Fire, and heated Braſs
225. Tube, is unfit for animal Reſpiration, is ſhewn by the
ſudden Death of any Animal put into a Receiver fill'd
226. therewith. Alſo Candles and living Coals, put into
227. this aduſt Air, immediately go out. Hence the noxious
and peſtilential Qualities of *Damps* and *ſuffocating Exhalations*, ſo frequent and fatally experienced in Mines, and other ſubterranean Places.

THAT Air in its natural State is neceſſary for *Fire*
Exp. 228. and *Flame*, is obvious from the *ſudden Extinction of a*
Candle, *a live Coal*, &c. in the *exhauſted Receiver*.
229. Alſo Gunpowder fired therein will not take Flame, or
be *exploſive*, but *melt and die away*.

THAT the different Velocities with which heavy and light Bodies
deſcend in the Air, is owing to the Air's Reſiſtance
Exp. 230. only, is manifeſt from the equal Velocity or Swiftneſs
with which all Bodies deſcend in the *exhauſted Receiver*, as is ſhewn in the Example of a *Guinea* and a *Feather*.

AIR is likewiſe neceſſary for the Exiſtence and Pro-
Exp. 231. pagation of Sounds; for a Bell placed under the Receiver,
and rung, will not be heard when the Air is
232. drawn out; but in condenſed Air, the Sound will be
augmented in proportion to the Condenſation.

THAT *Fermentation, Putrefaction*, &c. depend on the Air, and are promoted by it, is ſhewn by preſerving Fruit in their natural Bloom and Perfection through the Winter in an *exhauſted Glaſs*. Exp. 233.

THE Uſe of the *Diving-Bell* depends on the *Preſſure* and *Spring* of the Air: For ſince the Space which Air takes up is reciprocally as the Power compreſſing it, 'tis evident that at the Depth of 33 Feet of Water, where the Preſſure of the Atmoſphere is doubled, the Bell will be half fill'd with Water; at the Depth of 66 Feet it will be two Thirds fill'd; at the Depth of 99 Feet it will be three Fourths fill'd; and ſo on. Whence appears the Neceſſity of having the Veſſel in the Form of a *Bell*, that the perpendicular Height of the Water may be as little as poſſible. Hence alſo we ſee how neceſſary it is to have a very gentle Deſcent of the Bell, that the Divers may have Time to admit the Air, ſo greatly condenſed, by proper Degrees, leſt it ſhould burſt the fine Veſſels of their Bodies, and kill them: Together with ſeveral other Particulars relating to the Nature and Manner of uſing this Machine, which will be fully explain'd by Experiment. 234.

THE *Weight*, or *Spring* of the Air, or both, are moſt evidently concern'd in that Chirurgical Operation we call *Cupping*; for when a *Vacuum* is made by a Syringe in the Cupping-Glaſs applied to any Part, the *Spring* of the Air in the Fleſh under the Glaſs does ſtrongly act, and by that means cauſes the Fleſh to diſtend and ſwell into the Glaſs, while the Preſſure of the Air on the Parts without the Glaſs accelerates the Motion of the Blood and Fluids, towards the Part where it is diminiſh'd or taken off by the Glaſs. Exp. 235.

SINCE we know that *Heat* augments the repellent Power in the Particles of a Fluid, and by that means increaſes its Elaſticity, and thereby cauſes it to expand itſelf into a larger Space; and that *Cold* has a quite contrary Effect; Exp. 236.

fect; we learn the Uſe of the THERMOMETER in indicating the *various Degrees of Heat and Cold in the Air*, by the different Altitudes of the Spirit of Wine in that Inſtrument.

Exp. 237. THE *Moiſture* and *Dryneſs* of the Air are ſhewn by the HYGROMETER, which is made ſeveral ways, but that with a *Cord* is moſt common and uſeful; for that by ſhrinking with Moiſture will turn an Index one way, and extending with Dryneſs will turn it the contrary way, over the graduated Limb of a Circle.

I SHALL finiſh this Lecture with giving you an Account of the Structure and Uſe of the common AIR-PUMP, and of one of a *new Invention* of my own. The common or large Air-Pump is repreſented in *Fig.* XXIV. where *a a*, *a a*, are the two Braſs Barrels, in which the Piſtons *c c*, *c c*, move by Chains faſten'd to each of them, and to a Wheel moving on the Axle *f*, when the Engine is put into Motion by the Winch *b b*. *g g*, *g g*, are two Pillars or Pieces of Wood ſupporting the Frame of the Pump-Wheel, which is ſcrew'd upon them by Nuts under the little Pieces of Wood *e*, *e e*. The Tube or Pipe mark'd *h h* is call'd the *Swan-Neck*, made of Braſs: By this the Air paſſes from under the Receiver *o o*, through a ſmall Hole *k* in the Middle of the Braſs Plate *i i i* on the Top of the Pump, to a Braſs Piece in the Box *d d*, which being perforated length-ways to the Middle Point under each Barrel, does there, through a ſmall Hole, by a Bladder-Valve, tranſmit the Air from the Receiver into each Barrel to be pump'd out by paſſing through the Hole in the deſcending Piſton. Theſe Holes in the Piſtons and Bottoms of the Barrels are cover'd with Valves, to prevent the Return of the Air into the Receiver. *l l l* is the Mercurial Gage, or common Barometer, immerſed in a Baſon of Mercury *m m* fix'd in the Bottom of the Frame, and at top communicates with the Receiver, which therefore ſhews how much the Receiver is exhauſted by the Riſing of the Mercury in the Tube, by a graduated Scale affixed thereto. The

Stop-cock *n n*, alſo, communicates with the Receiver, and conſequently with the Swan-Neck and Mercurial Tube: Its Uſe is, by turning the Cock, to re-admit the Air, when there is Occaſion. The Receiver is ground true on the Bottom, and is fix'd on the Pump at firſt by means of wetted Leathers, to exclude the Air, inſtead of Cement formerly uſed for that purpoſe.

BUT with how much more Conveniency, and leſs Expence, Pneumatical Experiments of all Kinds may be perform'd, by a *new*, *elegant*, and *portable Air-Pump*, which I have lately contrived and made, will be eaſy to apprehend from a bare View of the Figure thereof: In which A B is the Head or Part containing the Wheel, which alternately raiſes and depreſſes the Piſtons C D in the Barrels E F, which are ſtrongly preſs'd down by the ſaid Part A B, ſupported on the two Pillars G H, fix'd into the Bed or Bottom of the Machine I K L. On this Bottom ſtands the Receiver M N on a large ſmooth Braſs Plate, in the Middle whereof is a Hole, by which the Air paſſes out of the Receiver into a ſmall Tube on the under Part of the Frame, and goes to the Piece O, which communicates with the perforated Braſs Piece on which the Barrels ſtand, and from which they receive the Air to be exhauſted. On the middle Part of this Braſs Piece is a Perforation, over which is placed a ſmall Receiver P Q, and under it a Baſon of Mercury R, in which a ſmall Tube R S (hermetically ſealed at one End, and fill'd with Quickſilver) is inverted; and therefore as the ſmall Receiver P Q is exhauſted, (at the ſame time with the large one M N) the Approach of the *Vacuum* will be ſhewn by the *Deſcent of the Quickſilver* in the Tube R S. By the Stop-cock T the Air is again let into the Receiver. *Fig.* XXV.

NOTE, This *Air-Pump*, with a *Receiver* large enough for any Uſe, may be together included in a Box 12 Inches wide, 14 high, and 14 in Length; which cannot be ſaid of any other Form yet invented. Nor can I at preſent ſee or think of any farther Improvement this Engine is capable of; unleſs it be, that in this Form a Pump might eaſily be made to exhauſt 6, 8, or 10 Receivers at once; which Hint may be well worth the Notice of Gentlemen of Spirit, Taſte, and Fortune.

LECTURE VII.

The Doctrine of WINDS *and* SOUNDS.

IN this Lecture I ſhall conſider the Nature of Wind and Sound in general; and of the Vibrations of *Muſical Strings* and *Sonorous Bodies*, with regard to the Science of MUSIC.

WIND is a *Stream* or *Current of Air:* As the Air is a Fluid, its natural State is that of *Reſt*, which it endeavours always to keep or retrieve by an univerſal *Equilibrium* of all its Parts. *Exp.* 238. When, therefore, this natural *Equilibrium* of the Atmoſphere happens by any means to be deſtroy'd in any Part, there neceſſarily follows a Motion of all the circumjacent Air towards that Part, to reſtore it; and this Motion of the Air is all we call *Wind*.

Hence, with reſpect to that Place where the *Equilibrium* of the Air is diſturb'd, we ſee the Wind may blow from every Point of the Compaſs at the ſame time; and thoſe who live *Northwards* of that Point have a *North Wind*; thoſe who live *Southwards*, a *South Wind*; and ſo of the reſt: But thoſe who live on the Spot, where all theſe Winds meet and interfere, are oppreſs'd with turbulent and boiſterous Weather, Whirlwinds and Hurricanes; with *Rain*, *Tempeſts*, *Lightning*, *Thunder*, &c. For *ſulphureous Exhalations* from the *South*, Torrents of *Nitre* from the

Plate IV.

Page 58.

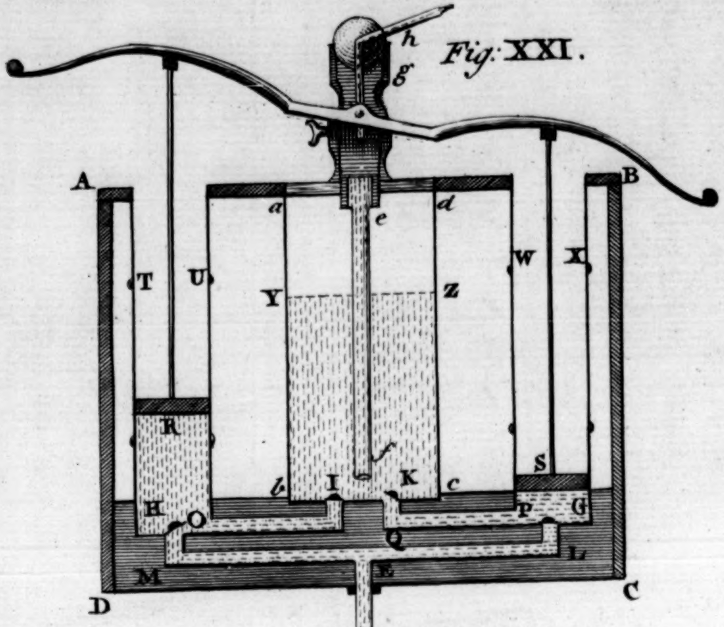


Fig: XXI.

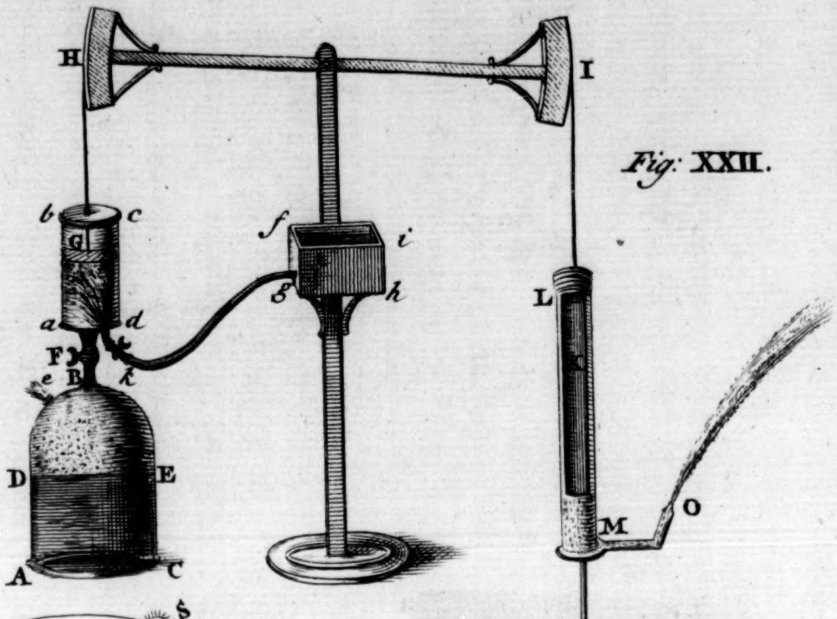


Fig: XXII.

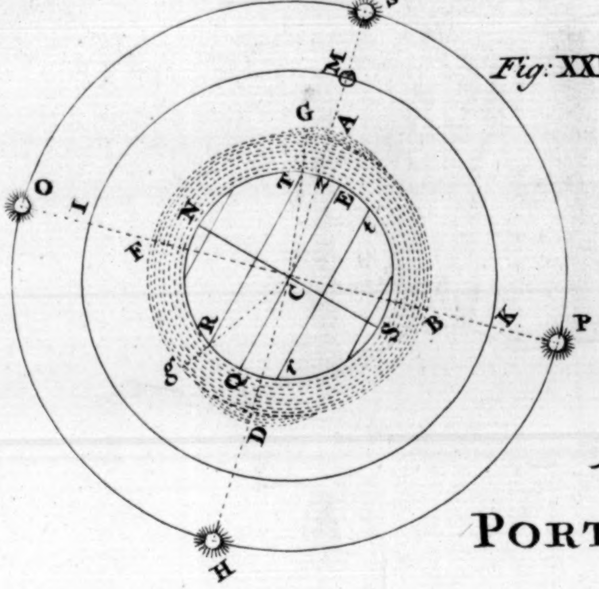


Fig: XXIII.

The
NEW-INVENTED
PORTABLE AIR-PUMP.

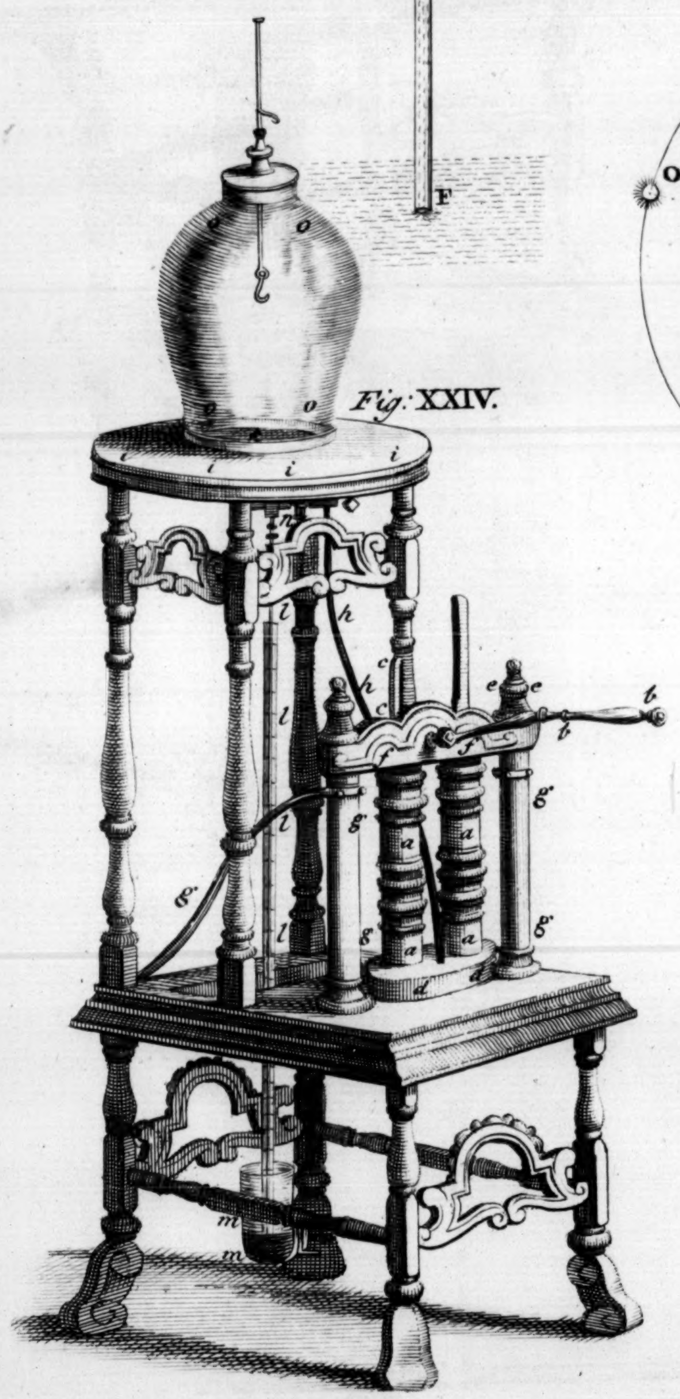


Fig: XXIV.

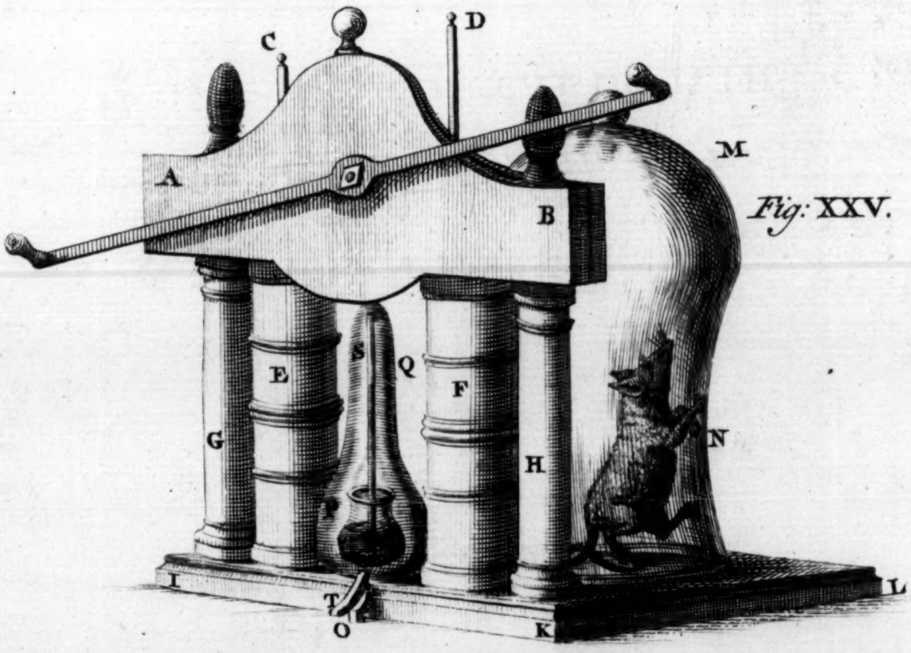


Fig: XXV.

E: Bowen sc.

the *North*, and *aqueous Vapours* from every Part, are there confuſedly huddled and violently blended together; and rarely fail to produce the *Phænomena* abovemention'd.

As the Motion of the Air has a greater or leſſer Velocity, the Wind is *ſtronger* or *weaker*; and it is found from Obſervation, that the Velocity of the Wind is various, from the rate of 1 to 50 or 60 Miles *per* Hour. *Exp.* 239.

Many are the particular Cauſes which produce Wind by interrupting the Equipoiſe of the Atmoſphere; but the moſt general Cauſes are two, *viz.* *Heat*, which, by *rarefying* the Air, makes it *lighter* in ſome Places than it is in others; and *Cold*, which, by *condenſing* it, makes it *heavier*. Hence it is, that in all Parts over the *Torrid Zone*, the Air being more rarefied by a greater Quantity of the Solar Rays, is much lighter than in the other Parts of the Atmoſphere, and moſt of all over the Equatorial Parts of the Earth. And ſince the Parts at the Equator are moſt rarefied which are near the Sun; and thoſe Parts are, by the Earth's diurnal Rotation *Eaſtward*, continually ſhifting to the *Weſt*; it follows, that the Parts of the Air which lie on the *Weſt* Side of the *Point of greateſt Rarefaction*, and, by flowing towards it, meet it, have leſs Motion than thoſe Parts on the *Eaſt* of the ſaid Point, which follow it; and therefore the Motion of the *Eaſtern Air* would prevail againſt that of the *Weſtern Air*, and ſo generate a *continual Eaſt Wind*, if this were all the Effect of that *Rarefaction*. But we are to conſider, that as all the Parts of the Atmoſphere are ſo greatly rarefied over the Equator, and all about the Poles greatly condenſed by extreme Cold, this heavier Air from either Pole is conſtantly flowing towards the Equator, to reſtore the Balance deſtroy'd by the *Rarefaction* and *Levity* of the Air over thoſe Regions: Hence, in this reſpect alone, a conſtant *North* and *South Wind* would be generated.

Now it is eaſy to underſtand, that by a Compoſition of theſe two Directions of the Air from the *Eaſt* and *North*, a *conſtant North-*

North-Eaſt Wind will be generated in the *Northern* Hemiſphere, and a *conſtant South-Eaſt Wind* in the *Southern* Hemiſphere, to a certain Diſtance on each Side the Equator, all round the Earth. And this Caſe we find to be verified in the *General Trade Winds*, which conſtantly blow from the *North-Eaſt* and *South-Eaſt*, to about 30 Degrees on each Side the Equator, where thoſe Parts are over the open Ocean, and not affected with the Reflection of the Sun-Beams from the heated Surface of the Land; for in this Caſe the Wind will always ſet in upon the Land, as on the Coaſt of *Guinea*, and other Parts of the *Torrid Zone*, we know it does; which alſo may be ſhewn by Experiment. *Exp.* 240.

THUS much may ſuffice for a general Account of the *Nature and Origin of Winds:* We proceed now to the *Doctrine of Sounds*. We know by the Experiment of the Bell in the exhauſted Receiver, that Sound has a neceſſary Dependance on the Air; and if we reflect on the Nature of the Particles of a ſonorous Body and thoſe of Air, we ſhall find that Sound is nothing but the Propagation of the Tremors and Vibrations of the former impreſs'd on the latter, to the *Tympanum* or Drum of the Ear, by whoſe Action they are communicated to the Air in the internal Cavities of the Ear, where the *Auditory Nerve* receives the Impreſſion, and excites the Senſation in the *Common Senſory* in the Brain.

Exp. 241. FOR the Parts of a ſonorous Body, being put into Motion by Percuſſion, do vibrate forwards and backwards through very ſmall Spaces, by their elaſtic Quality. In this Action, they affect the Particles of Air contiguous to them, and compel them upon the firſt Impulſe to move forwards alſo; and theſe propel the next, and ſo on, to a very conſiderable Diſtance, according to the Intenſity of the percuſſive Force. By this means the Particles of Air are compreſs'd nearer together, than in their natural State.

BUT when the Particles of the ſonorous Body make the ſecond Part of the Vibration, by returning back again, the Particles of

Air alſo, by their repulſive Power, repel each other towards their proper Places, and thus again expand themſelves.

Now ſince Motion once generated in elaſtic Bodies continues ſome time before it can be deſtroy'd by the Reſiſtance and Counteraction of contiguous Bodies, it follows, that the Particles of the ſonorous Body, and conſequently thoſe of the adjacent Air, have, for ſome time, a reciprocal vibratory Motion, by going forwards and backwards through very ſmall Spaces in an indefinitely ſmall Particle of Time; which Motion gradually decreaſes, till it be totally deſtroy'd. This may in a good meaſure be made eaſy to be underſtood by an Experiment of a *vibrating and ſpiral Wire.* *Exp.* 242.

FROM the Nature of a Fluid, whatever Motion is generated in any one Particle, it is by that Particle communicated equally to all around it, as from a Center; conſequently the Tremors of the ſounding Body will be propagated all around from the Point of Percuſſion, as a Center, in *concentric hollow Superficies or Shells of Air*, which are not improperly call'd *aerial Pulſes*, or *Waves of Air:* Analogous to which are the circular Waves generated on the Surface of Water all around the Point where any Impreſſion is made, in any Manner or Direction whatſoever. Theſe Pulſes or Waves of Air are affected with the following Properties, *viz.*

I. *They are propagated all around, in a ſpherical undulatory Manner* (as I ſaid but now;) and that not only from the tremulous Body, but from the Holes in any Obſtacles they meet with: Whence it comes to paſs, that *one and the ſame Sound may be heard by ſeveral Perſons*, in any different Situations with reſpect to the ſounding Body, if not at too great a Diſtance.

II. *The Denſity of theſe aerial Pulſes decreaſes, as the Squares of the Diſtances from the ſounding Body increaſe:* For ſince the Force or Motion in each Shell is the ſame, it muſt decreaſe as the Number of Particles increaſes in each Shell: But this Number of Particles is as the Superficies of the Shell, which is as the Squares of the Diameter or Semidiameter of the Sphere, that is, as the Diſtance from the ſounding Body. Hence the Diſtinction of Sounds into *loud* and *low*, *ſtrong* and *weak*, according as we are nearer to, or farther from, the ſounding Body. *Exp.* 243.

The utmoſt Limits of *audible Sounds* are about 180 or 200 Miles.

III. *All the Pulſes, whether denſer or rarer, move with equal Velocities:* This Sir *Iſaac Newton* has demonſtrated *a priori*, and alſo that this Velocity is at the rate of 1142 Feet in one Second of Time; which moſt exactly agrees with the repeated and moſt accurate Experiments of the late Reverend Mr. *Derham*. *Exp.* 244. The Velocity of Sound is therefore near thirteen times as great as that of the ſtrongeſt Wind: And ſince it muſt neceſſarily increaſe with the Air's Elaſticity, it will be greateſt in Summer when the Air is moſt heated, and *vice verſa* in Winter: Alſo, as the Motion of the Wind conſpires with, or is contrary to that of Sound, the Velocity of Sound will be in ſome ſmall Degree augmented or diminiſhed thereby, though not diſcernible in Experiments.

IV. *The Interval or Diſtance of the Pulſes from each other is the ſame among all that are excited by the ſame Stroke:* For ſince each Pulſe is cauſed by a ſingle Vibration of the ſounding Body, and ſince they all move with equal and uniform Velocities, 'tis plain they muſt ſucceed each other at Intervals proportion'd to the Times of the Vibrations: But the Times of the Vibrations of the ſame Body are all equal; conſequently, the Intervals of the Pulſes will be ſo too.

V. *The aerial Pulſes are propagated together in great Numbers from different Bodies without Diſturbance or Confuſion*; *Exp.* 245. as is evident from Concerts of Muſical Inſtruments, where divers Sounds, of different Intervals and various Coincidences, ſtrike the Ear at once, yet with Diſtinctneſs and agreeable Conſonance.

VI. *The Particles of Air, and conſequently the Pulſes, ſtriking againſt an Obſtacle, will be reflected back under an Angle equal to that of Incidence*; in the ſame manner as will be ſhewn in regard to the Rays of Light. Hence a *Repetition of the Sound*, heard by the direct Pulſes, will be made by thoſe which are reflected; which is what we call an ECHO. Exp. 246.

The Locus, *or audible Place of Sound*, will be there where the Particles of Air firſt begin to diffuſe themſelves in Form of Waves. Thus a Perſon ſpeaking in one End of a Tube, or Trumpet, will be heard as ſpeaking from the other. And as in the Caſe of Light, we ſee the Image of an Object always in the Direction of the reflected Ray; ſo in *Echoes*, we hear a Perſon ſpeak at the Place from whence the reflected Wave comes to the Ear. Exp. 247.

BECAUSE the Sound is ſtronger in proportion as the Air is denſer, it muſt follow, that the Voice paſſing through a Tube or Trumpet muſt be greatly augmented by the conſtant Reflection and Agitation of the Air through the Length of the Tube, by which it is condenſed, and its Action on the external Air greatly increaſed at its Exit from the Tube; which from hence is call'd the *Stentorophonic Tube*, or *Speaking-Trumpet*. Exp. 248.

FOR the ſame Reaſon, thoſe Funnel-like Inſtruments, which gather the larger and more languid Waves of Air, do greatly condenſe them, and heighten their Power and Action on the Drum of the Ear; by which means, Voices and Sounds are render'd *ſtrong*, *loud*, and *audible*, which were not ſo before to a deafen'd Ear; and hence theſe Inſtruments come to be call'd *Otacouſtics*. Exp. 249.

I SHALL only obſerve, in regard of thoſe Inſtruments which magnify Sounds, and aſſiſt the Hearing, that *the longer they are, the greater is their Effect*; and that of all the Forms or Shapes, none is ſo good as *that derived from the Revolution of the Logarithmic Curve about its Axis.*

FROM the fourth Property of the *aerial Pulſes* we have the Origin of the various Degrees of what we call the *Note*, *Tone*, or *Tune* of Sounds, in regard of which they are diſtinguiſh'd into *low* and *high*, or *grave* and *acute*, by Muſicians call'd *Flats* and *Sharps*. Now the Tone of a Sound depends on the Time or Duration of the Stroke made on the Drum of the Ear, by a Wave or Pulſe of Air; for as that is longer or ſhorter, the Tone will be more *grave* or *acute:* And ſince all the Pulſes move equally ſwift, the Duration of a Stroke will be proportional to the Interval between two ſucceſſive Pulſes; and conſequently, *a Sound is more or leſs Grave or Acute in proportion to the Length of that Interval.*

HENCE it follows, that all the Sounds from the *loudeſt to the loweſt*, which are excited by the Vibrations of the ſame Body, are of *one Tone*. It likewiſe follows, that all thoſe Bodies whoſe Parts perform their Vibrations in the ſame or equal Times, have the ſame Tone: Alſo, thoſe Bodies which vibrate *ſloweſt*, have the *graveſt* or *deepeſt Tone*; as thoſe which vibrate *quickeſt*, have the *ſharpeſt* or *ſhrilleſt Tone*. *Exp.* 250. *Exp.* 251.

THE Times of the Vibrations of *Muſical Strings*, and conſequently the Tones, vary in reſpect of the *Length*, the *Magnitude*, and the *Tenſion* of thoſe Strings. For if two Strings A B, C D, are of the ſame Magnitude, and ſtretch'd by equal Weights E, F, have their Lengths as 2 to 1, the Times of their Vibrations will be in the ſame Ratio. Hence the Number of Vibrations of the two Strings A B, C D, perform'd in the ſame Time, *will be inverſely as their Lengths*; or C D will make two Vibrations, while A B performs one. The Vibrations of two ſuch Strings will therefore co-incide at every ſecond of the leſſer. *Exp.* 252.

AGAIN: If two Strings AB, CD, have their Diameters as 2 to 1, and are of equal Length, and tended by equal Weights E, F; *the Times of the Vibrations will be as their Diameters, viz.* as 2 to 1; and ſo the Vibrations in a given Time, and the Co-incidences, as before. *Exp.* 253.

LASTLY: If the Diameters and Lengths of the Strings be equal, *the Times of the Vibrations will be inverſely as the Square Roots of the Weights which ſtretch them.* If the Weights E and F be as 1 to 4 (the Square Root of which are 1 and 2) then the Times of Vibration in AB and CD will be as 2 to 1. Hence in *conſtructing ſtring'd Inſtruments*, as *Spinets*, *Harpſichords*, &c. a ſkilful Artiſt will compound theſe Proportions of the *Length*, *Diameter*, and *Tenſion* of the Strings to very great Advantage. *Exp.* 254.

IN *Wind-Inſtruments*, as the *Flute*, *Organ*, &c. where the Sound is made by the *Vibration of a Column of elaſtic Air* contain'd in the Tube, the Time of Vibration or Tone of the Inſtrument will alſo vary with the *Length and Diameter of the ſaid Column of Air*, *and Force of the Voice*, which compreſſes it; as will be eaſy to obſerve from Experiments. *Exp.* 255.

IF one Body be made to ſound with another, their Vibrations will co-incide after a certain Interval; and the ſhorter the Interval of the Co-incidence, the more agreeable is the Effect or Conſonance to the Ear; conſequently, thoſe which are moſt frequent produce the moſt perfect Conſonance or *Concord*, as it is commonly call'd. When the Times of Vibration, therefore, are equal, the *Concord* is moſt perfect and more agreeable than any other, and this is call'd *Uniſon*. *Exp.* 256.

IF the Times of Vibration are as 1 to 2, the Co-incidence will be at every ſecond Vibration of the quickeſt, and ſo this is the next perfect Concord, and is what we commonly call a *Diapaſon* or *Octave*. *Exp.* 257.

IF the Times of the Vibration be as 2 to 3, the Co-incidence will be at every third Vibration of the quickeſt; which therefore is in the next Degree of Perfection, and this is call'd a *Diapente*, or *Fifth*. If the Times of Vibration are as 3 to 4, the Co-incidence will be at every 4th of the leſſer; and this is call'd the *Diateſſaron* or *Fourth*. But this, and the next which follow in order, are not ſo agreeable and pleaſant to the judicious Ear, and are therefore call'd *Imperfect Concords*. Nor are there above *ſeven Notes* in all the infinite Variety of Tones, which can merit a Place in Muſical Compoſitions, and they are exhibited in *Fig.* XXIX. which repreſents the Strings in an Octave of a Harpſichord, with the *Semitones* or *Half-Notes*, call'd *Flats* and *Sharps*, by which the Natural Notes are made half a Note lower or higher, as the Air of the Song or Muſick requires. And this is call'd the *Diatonic Scale* of Muſic.

Exp. 258.

Exp. 259.

Exp. 260.

IN this Scale, the ſeven natural Notes are mark'd on the Keys by the ſeven Letters C, D, E, F, G, A, B. The firſt of which is call'd the *Fundamental* or KEY; the reſt in Order are the *Second Greater*, the *Third Greater*, the *Fourth Greater*, the *Fifth*, the *Sixth Greater*, the *Seventh Greater*, and then the *Eighth*, which begins the next Octave. Between theſe are interpoſed the five *Semitones*, *viz.* the *Second Leſſer*, the *Third Leſſer*, the *Fourth Greater*, the *Sixth Leſſer*, the *Seventh Leſſer*. Theſe ſeveral Tones and Semitones have the Lengths of the Strings adjuſted from the Diviſion of the *Monochord*, or Line divided into 100 or 1000 equal Parts, as is very eaſy to apprehend from the Figure.

THE Number of thoſe Diviſions are alſo ſhewn for each String, by the firſt Series of Numbers on the Strings; the next Series ſhew the Proportion of the Length of each String to that of the *Key*, or *Monochord*; and conſequently the Number of Vibrations of the Fundamental and each String reſpectively, perform'd in the ſame Time.

OF theſe *twelve Intervals* or Ratios of Muſical Sounds, the *Octaves* and *Fifths* are *perfect Concords*; the third Greater, third Leſſer, the Greater and Leſſer Sixth are *imperfect Concords*; the Greater Fourth, the two *Seconds*, and two *Sevenths* are *Diſcords*; the *Fourth* is in its own Nature a perfect *Concord*, but lying between the Third and Fifth, it cannot be uſed as ſuch, but when join'd with the Sixth, to which it ſtands in the Relation of a Third. All *Melody* and *Harmony* are compos'd of theſe twelve Notes; for the Octaves above or below are but the Replications of the ſame Sounds in a higher or lower Tone. *Melody* is the agreeable Succeſſion of ſeveral Muſical Sounds in any ſingle Piece of Muſic; as *Harmony* is the Effect of ſeveral of thoſe Pieces or Parts of Muſic play'd together.

Harmonical Proportion is that which is between
thoſe Numbers which aſſign the Lengths of Muſical Exp. 261.
Intervals, or the Lengths of Strings ſounding Muſical
Notes; and of *three Numbers* it is, *when the Firſt is to the Third, as the Difference between the Firſt and Second is to the Difference between the Second and Third*; as the Numbers 3, 4, 6. Thus if the Lengths of Strings be as theſe Numbers, they will ſound an *Octave*, 3 to 6; a *Fifth*, 2 to 3; and a *Fourth*, 3 to 4.

AGAIN: *Harmonical Proportion* between four Num-
bers is, when *the Firſt is to the Fourth as the Dif-* Exp. 262.
*ference between the Firſt and Second is to the Diffe-
rence between the Third and Fourth, as in the Numbers* 5, 6, 8, 10: For Strings of ſuch Lengths will ſound an *Octave*, 5 to 10; a Sixth Greater, 6 to 10; a Third Greater, 8 to 10; a Third Leſſer, 5 to 6; a Sixth Leſſer, 5 to 8; a Fourth, 6 to 8.

IT may be here obſerved, *that a Series of Num-
bers in Harmonical Proportion are reciprocally as* Exp. 263.
another Series in Arithmetical Progreſſion,

$$\text{As}\left\{\begin{array}{lcccccc}\text{Harmon.} & 10: & 12: & 15: & 20: & 30: & 60:\\ \text{Arithmet.} & 6: & 5: & 4: & 3: & 2: & 1:\end{array}\right\}$$

for here 10 : 12 :: 5 : 6; and 12 : 15 :: 4 : 5; and ſo of all the reſt. Whence thoſe Series have an obvious Relation to, and Dependence on, each other; which in ſome Problems of ſpeculative Philoſophy will be very uſeful to know.

Fig. XXX. IF the three Lines AD, BG, CH, be taken in Muſical Proportion, or as the Numbers 6, 4, 3; and in the Line AD we take AE equal to BG, AF equal to CH, *then will the Line* AD *be divided in Harmonical Proportion*, in the Points A, F, E, D; *viz.* AD : AF :: DE : EF.

Exp. 264. And in this manner is the Axis of a Convex and Concave Mirrour divided by the *Object*, the *Image*, the *Vertex of the Mirrour*, and the *Center*, as may be eaſily ſhewn by Experiment.

ALSO the Limits of the Colours of Light, as ſeparated by the Priſm, *fall upon the ſeven Muſical Diviſions of the Monochord*; as will be farther taken notice of, and exemplified in the next Lecture.

Exp. 265. I SHALL conclude this with taking notice of one ſingular Property of a Muſical Chord, *viz.* that it will be put into a vibratory Motion by the Pulſes of the Air proceeding from the Vibrations of another very near it, and in Concord with it: If the vibrating String be *Uniſon* with it, the other will tremble through its *whole Length*; if an *Octave*, it will vibrate by the Half-Lengths only; if the String which communicates the Motion be a *Double-Octave above*, or *one Fourth* of the Length of the other, the Motion will be ſtill correſpondent in that other String, for it will vibrate only by the *Fourths of its Length* from one End to the other. Thus if AB be a *Fi.* XXXI. String four Feet long, and CD another of one Foot; if the latter be ſtruck with a Quill, the Vibrations will be communicated to the former in ſuch a manner that it will vibrate only by a *Foot-Length* at the ſame time through the whole String; which will be evident by the ſmall Pieces of Paper *b*, *d*, *f*, *h*, hung upon the Middle of every Foot-Length, ſuddenly leaping off; while the other Pieces *a*, *c*, *e*, *g*, *i*, remain unmoved upon the String at the End of every Foot, where the Vibrations ſeverally begin and end, and conſequently where the Line has no Motion at all.

LECTURE VIII.

Of LIGHT *and* COLOURS.

THAT *Light* is not a *mere Quality* of ſome Bodies, but is itſelf a real Body, or diſtinct Species of Matter, and endued with all the natural Properties thereof, will, I preſume, be ſufficiently manifeſt from the following Experiments relating thereto. We ſhall therefore, at preſent, take it for granted, *that Light conſiſts of inconceivably ſmall Particles of Matter of different Magnitudes, which are emitted or reflected from every Point in the Surface of a luminous Body in right Lines, and in all Directions, with an unparallel'd Velocity, and whoſe Power or Intenſity decreaſes as the Squares of the Diſtances increaſe.*

THAT the Particles of Light, refracted through the Humours of the Eye to the *Retina*, or fine Expanſion of the Optic Nerve over all the interior hinder Part of the Eye; and there, by painting the Images of external Objects, become the immediate Means of Sight, will be fully ſhewn in the next Lecture.

WE ſhall now conſider Light under the various Characters and Qualities of a Natural Body, and point out thoſe remarkable Affections and Properties ſo peculiar to itſelf, and the Cauſes of ſo many very curious and extraordinary Phænomena in Nature.

THAT the Particles of Light are *inconceivably ſmall*, Exp. 266. is evident from hence, that the greateſt Quantity of Light, in the State of greateſt Denſity, or *Flame*, is found to have ſcarce any ſenſible Gravity or Weight, which, we have ſhewn, is always proportional to the Quantity of Matter in all Bodies: Alſo, becauſe thoſe Particles pervade the Pores of all tranſparent Bodies, however hard or heavy, as Glaſs and Adamant. But we know it more eſpecially from hence, that the Stroke we receive by a Particle of Light has no ſenſible Force or *Momentum*, which, on account of its prodigious Velocity, would be very great, and inſufferable, were it of any aſſignable or conſiderable Magnitude.

YET ſmall as they are, we find the Rays conſiſt of different Sorts of Particles in Light emitted from all Bodies; and that this Difference of the Rays of Light ariſes from the different Magnitude of the Particles, ſeems moſt evident from the different Directions the ſeveral Sorts of Rays move in, after they have paſs'd through a Body of Glaſs, Water, &c. of ſome ſpecial Figure, as that of a *Priſm* eſpecially.

THAT the Particles of Light are emitted from every Point in the Surface of a Body, is evident from hence, that any given Point in that Surface is viſible to the Eye in any Situation, from whence a Right Line can be drawn from the Eye to that Point; which could not be, if the Light were not propagated from that Point in all Directions.

THAT they proceed from the Body in Right Lines, Exp. 267. is clearly ſeen by Experiments on the Sun-Beams, Candle-Light, &c. in a darken'd Room; alſo from the Shadows which Bodies of every Figure caſt, being ſuch as would be determined by Right Lines drawn from the luminous Point touching the Extremities of thoſe Bodies.

THE Velocity of the Rays of Light ſurpaſſes that of Exp. 268. all other Bodies we know of. By obſerving the Times of the Eclipſes of *Jupiter*'s *Satellites* when the Earth is neareſt, and again when it is fartheſt diſtant from that Planet, we ſhall find, that in the former Caſe thoſe Eclipſes happen *too ſoon*, and in the latter *too late*, by the Space of about *ſeven Minutes*; which ſhews, that in that Time the Light paſſes over the Semidiameter of the Earth's Orbit, which is about 82000000 Miles; which is at the rate of 200000 Miles in a Second of Time, and which is therefore nearly 800000 times greater than the Velocity of Sound.

AGAIN: Since Light is propagated in Right Lines, its Power or Intenſity will decreaſe as the Squares of the Diſtances increaſe; and therefore the Light and Heat of the Sun at the Diſtances of the Six Planets, *Mercury*, *Venus*, *Earth*, *Mars*, *Jupiter*, and *Saturn*, will be nearly as 700, 200, 100, 43, 3, 1. ſuppoſing their Diſtances as the Numbers 4, 7, 10, 15, 52, 95.

FROM the ſtupendous Velocity of luminous Particles ariſe their prodigious Effects in regard of *Heat*, *Flame*, *Burning*, *Melting*, *&c.* Thus when they are conſiderably denſe, they act very forcibly on the Parts of an animal Body, and raiſe the *Senſation of Heat*, by the great inteſtine Motion which they produce in every Part. Hence all other Bodies are *hotter* or *colder*, as they contain a greater or leſſer Quantity of ignitious Particles, and ſo have a greater or leſſer Degree of inteſtine Motion of the Parts.

IF theſe lucific Particles are ſufficiently imbibed or generated in any opake Body, they cauſe it to ſhine, Exp. 269. or glow, or become red-hot; and by their prodigious Activity will in time diſunite, diſſolve, and deſtroy its natural Texture, and thus change its Form, and reduce it to another Species of Matter; even the *Aſbeſtos* not excepted. Exp. 270.

IF the ignific Particles of Light are ſufficiently condenſed, as the Rays of the Sun by a *Lens* or *Burning-Glaſs*, 271. they become *ardent*, and burn with an Intenſity proportional to the Denſity of the Rays in the *Focus*, or Burning-

Point of the Glaſs; which *burning Spot*, or *circular Space*, is always *as the Area of the Burning-Glaſs directly, and the Square of the Focal Diſtance inverſely.* Thus, ſuppoſe the Surface or Area of one Glaſs contain'd 12 Square Inches, and its Focal Diſtance were 8 Inches; and the Area of another Glaſs were 9 Square Inches, and its Focal Diſtance 4 Inches; then the Effects or Intenſity of Burning would be as $\frac{12}{64}$ to $\frac{9}{16}$, or as 12 x 16 to 9 x 64, *viz.* as 197 to 576. Or 1:3.

WHEN Rays of Light fall on the Surface of an opake
Exp. 272. Body, part thereof are reflected to the Eye, which render it viſible; the other Part is tranſmitted, and variouſly reflected through the Pores of the Body, till it becomes totally ſuffocated and loſt therein; and ſince none of thoſe Rays come from the interior Parts to the Eye, we can ſee nothing of the internal Subſtance of ſuch a Body, which therefore is ſaid to be *opake*.

BUT when Rays of Light fall on *tranſparent Bodies*,
Exp. 273. part is reflected at the firſt Surface, and part is tranſmitted into the Body, which is refracted in Right Lines to the ſecond or lower Surface, where it is again partly reflected and in part refracted into the Air, and coming to the Eye, renders the internal Parts of thoſe Bodies viſible, which for that Reaſon are ſaid to be *diaphanous* or *tranſparent*.

WHEN a Ray of Light H C falls on any plain, con-
F. XXXII. vex, or concave Surface, as AB, DE, FG, in the Point C, the Angle HCK, made by the incident Ray HC and the Perpendicular KC, is always equal to the Angle KCI, made by the ſaid Perpendicular and the reflected Ray CI: Or the Angle of Incidence is equal to the Angle of Reflection in every Inclination of the Ray of Light. This is evi-
Exp. 274. dently ſhewn by Experiment; and it is very well worth our Obſervation, that in this Caſe only, the ſaid Ray takes the *ſhorteſt Way poſſible* from any Point H, to any other

Point I, if it muſt, in its Paſſage, touch any of thoſe Surfaces.

The Rays of Light reflected from the firſt Surface of a Glaſs are more copious than thoſe reflected from *Exp.* 275. the ſecond Surface, as is evident from hence, that the Image form'd in the firſt Caſe is more bright and ſplendid than that of the latter; and if the ſecond Surface be contiguous to any tranſparent *Medium*, as Air, Water, *&c.* the Rays will be reflected from thence in greater Plenty, as the *Medium* is more rare; whence the Image by Reflection from the ſecond *Exp.* 276. Surface is brighter when that Surface is contiguous to Air, than when it touches Water; and moſt bright when it is contiguous to a *Vacuum*.

If the ſecond Surface of Glaſs be cover'd with an opake Body impervious to the Rays of Light, they will *Exp.* 277. then be reflected in much greater abundance from the ſecond than from the firſt Surface, and the Image will be proportionally more bright than that form'd by Reflection from the firſt Surface; which is the Caſe of all Glaſſes foliated or quickſilver'd. Whence it appears, that the Light reflected from the firſt Surface bears a very ſmall Proportion to that which is tramitted into the Subſtance of the Glaſs.

When a Ray of Light, as HC, paſſes out of Air into a denſer Medium, as ABFO, it will be ſtrongly *F.*XXXIII. attracted by the Particles of the Surface of the Medium AB, a little way on each Side; the Conſequence whereof is, that its Motion will be accelerated at the Entrance of the Medium, and its Direction ſomewhat alter'd; for ſince *Exp.* 278. the Attraction of the Medium is perpendicular to its Surface, it will deflect or bend the Ray out of its firſt Direction HF, into a new one CE, (through the *Medium)* which lies nearer to the Perpendicular KD, drawn through the Point of Incidence C: And this is call'd the Refraction *of a Ray of Light*;

HCK is the Angle of Incidence, and DCE the Angle of Refraction.

IF on the Point C be deſcribed a Circle DHKG, and from the Points H and G (where the Circle cuts the incident and refracted Ray) be drawn the Lines HL, GI, at right Angles to the Perpendicular KD, they will be the *Sines of the Angles of Incidence and Refraction*. And it is ſeveral ways demonſtrable, that in every Inclination of the Ray of Light HC to the Surface of the Medium AB, thoſe two Sines HL and GI will always have one certain or conſtant Ratio or Proportion to each other: And that HL : GI :: 4 : 3, if the Refraction be out of *Air* into *Water*; but HL : GI :: 17 : 11, or 3 : 2 nearly, if out of *Air* into *Glaſs*; and and in general, the denſer the Medium, the greater its refractive Power, or Diſproportion of the Sines; all which Particulars will be very evident by Experiments. *Exp.* 279. *Exp.* 280.

IF a Ray of Light, as EC, paſs out of a denſer Medium into a rarer, as a *Water* or *Glaſs* into *Air*, it will, upon entering the rarer Medium at C, be refracted from its firſt Direction EN into a new one CH, which will be farther off from the Perpendicular KCD; and in this Caſe, IG will be the Sine of the Angle of Incidence, and HL that of the Angle of Refraction; and all other Particulars juſt the reverſe of what they were before under the ſame Names.

Exp. 281. HENCE it follows, that if any Object be placed at E, and cover'd with Water to the Height CD, it will be ſeen by an Eye placed any where above the Surface AB, in a Situation lower than would be otherwiſe poſſible; and thus Objects which are inviſible may be render'd viſible by the Interpoſition of a denſer Medium, as is well known by a common Experiment. On this account it is that we ſee the Sun, and other Luminaries, while they are yet below the Horizon, in a Morning before they riſe, and in the Evening after they are ſet, by the Refraction

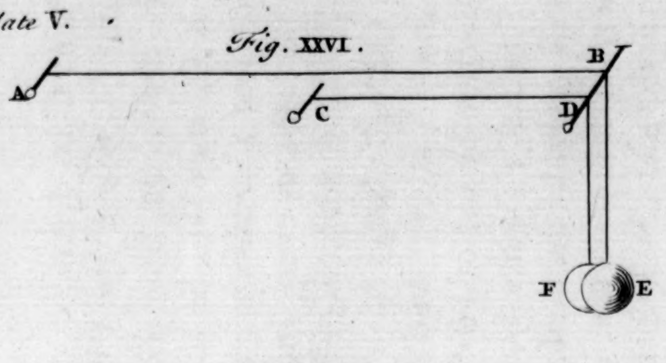


Fig. XXVI.

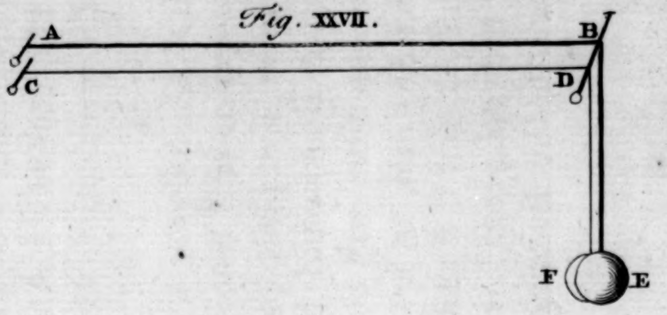


Fig. XXVII.

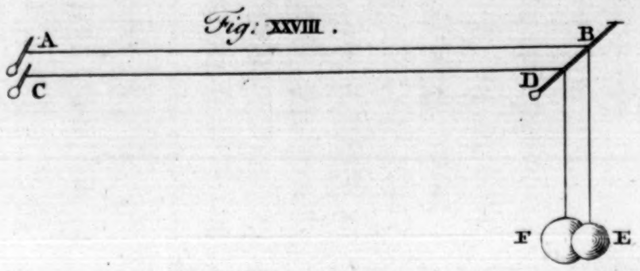


Fig: XXVIII.

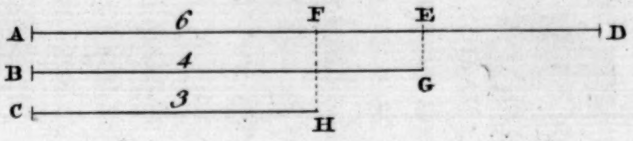
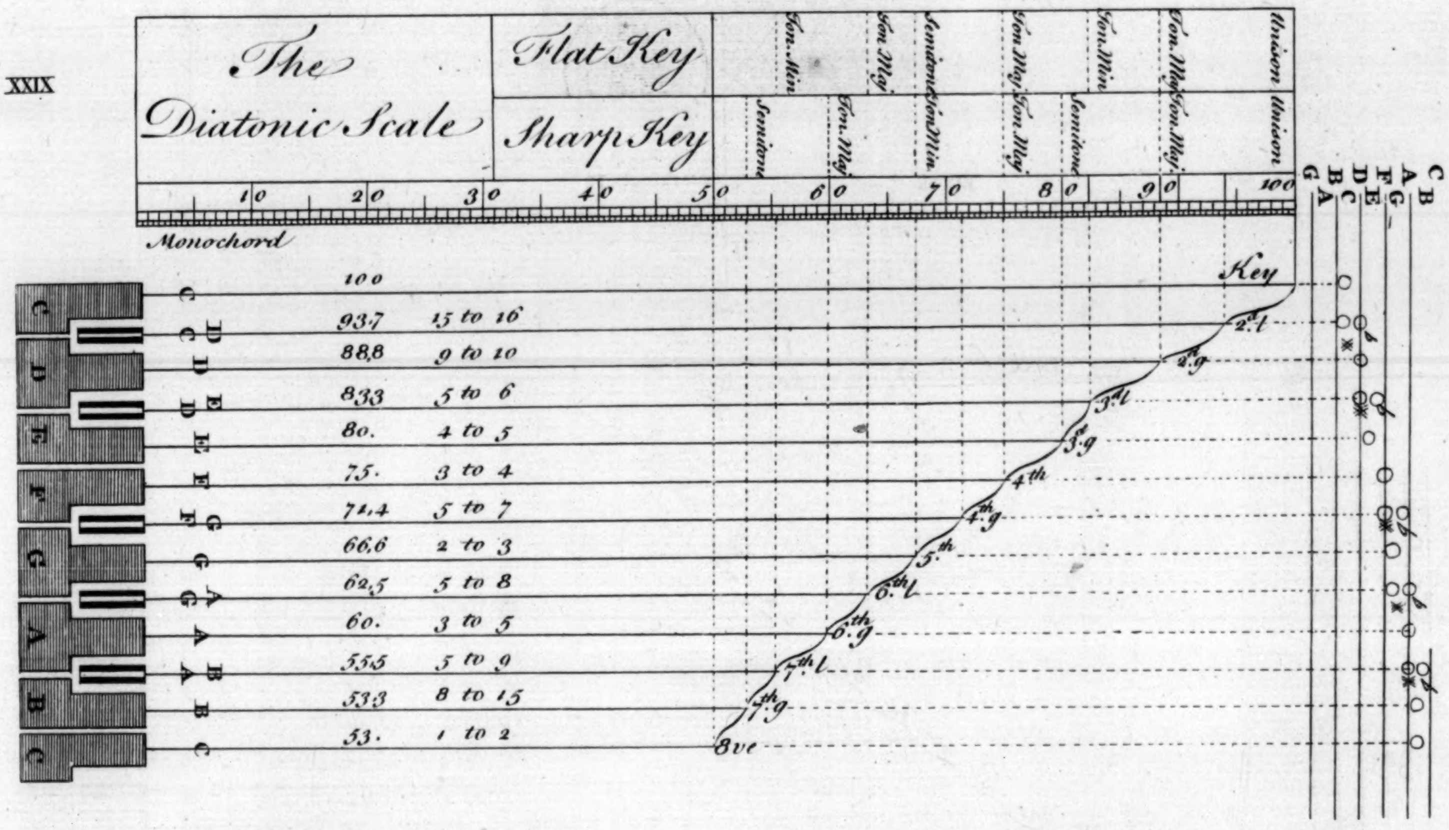


Fig. XXX.

Fig XXIX



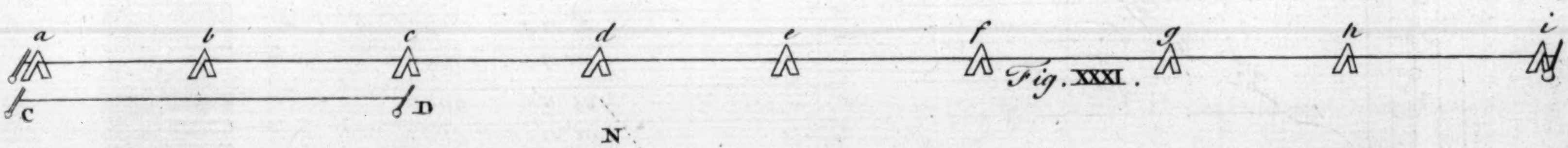


Fig. XXXI.

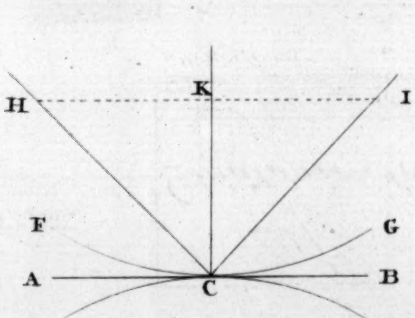


Fig. XXXII

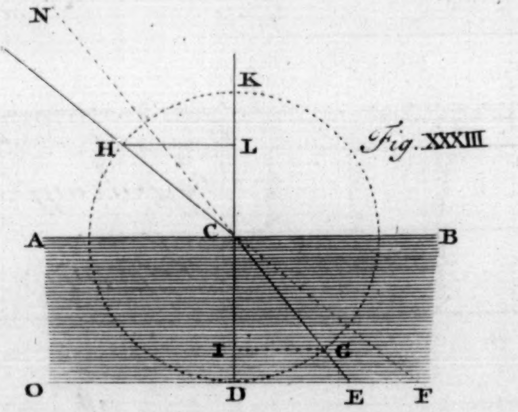


Fig. XXXIII

E. Bowen sc.

fraction of the Atmoſphere. Hence alſo the Difference in the Diameters of the *Horizontal Sun and Moon*, and their *Elliptic Figure*, by the greater Refraction of the Rays coming from the lower Limb.

AGAIN; it follows, that if an Object be view'd which is part in one Medium and part in another, as *Exp.* 282. a Staff repreſented by NE, it will not appear *ſtrait*, but *crooked*; for if the Eye be in the rarer Medium, the Part of the Staff in the denſer, CE, will be refracted into the Line CF, and the whole Staff will appear in the crooked Form NCF.

HENCE alſo all Objects in a denſer Medium appear raiſed or elevated above their real Situations: Thus the *Exp.* 283. Part of the Staff CE is raiſed into the Situation CF; and the Bottoms of all Veſſels, if cover'd with Water, 284. appear raiſed, or higher by a fourth Part of the Depth 285. of the Water, than what they really are.

THE Sun's Rays, as I have ſaid, are not homogeneous, but of different Kinds; and each Sort has a different Degree of Refrangibility; that is, in paſſing through a denſe Medium, they are differently diſpoſed to be refracted, being bent or turn'd out of their firſt Courſe to different Diſtances from the Perpendicular: And theſe ſeveral Sorts of Rays have each a peculiar Colour, *viz.* thoſe which are leaſt refrangible are *Red*; the ſecond Sort, *Orange*; the third Sort, *Yellow*; the fourth Sort, *Green*; the fifth Sort, *Blue*; the ſixth Sort, *Indigo*; and the ſeventh Sort, *Violet*, which are moſt refrangible, or refracted to the greateſt Diſtance from the Perpendicular.

To illuſtrate this Matter, let GF repreſent a Parcel of the Solar Rays entering through the Hole H of a *F.*XXXIV. Window-Shutter, into a darken'd Room; and there *Exp.* 286. let them fall on the Priſm ABC, in the Point F: In paſſing through the Priſm they will be ſeverally refracted in a different Degree, and thus ſeparated from each other, ſo that at their Exit on the other Side at E, they will proceed at different Diſtances from the Perpendicular EP to the other Side of the Room, where they will make a long and various-colour'd Image of the Sun XY, which is, perhaps, one of the moſt ſurprizing and agreeable Spectacles of Nature.

THE ſeveral Sorts of Rays, after they are refracted, appear in their own proper Colours in Order as follows, *viz.* Thoſe which are leaſt refracted, or fall neareſt the Perpendicular PE are *Red*, and make the red Part of the *Spectrum* at R; the next are the *Orange* at O, the *Yellow* at Y, the *Green* at G, the *Blue* at B, the *Indigo* at I, and the *Violet* at V: And theſe Seven are all the *original ſimple Colours in Nature*; and of which, by various Mixtures, all others are compounded, in the common Refractions and Reflections from natural Bodies.

SINCE a Lens does, in the manner of a Priſm, more *Exp.* 287. or leſs ſeparate the Rays of Light paſſing through it, it follows, that all the ſeveral Sorts of Rays will have their proper *Focus's*, or be convened to ſo many different Points in the Axis of the Lens, and not all to one Point only, as is neceſſary for a perfect and uniform Repreſentation of the Image of any Object: For the Red Rays proceeding from the Object will be converged to a *Focus* at a greater Diſtance from the Lens, than the Indigo or Violet Rays; and ſo the Image will be colour'd and confuſed in every Point between thoſe Extremes, except *Exp.* 288. juſt in the middle Point, where the ſeveral Sorts of Rays all interſect each other, and exhibit the Image tolerably diſtinct and colourleſs. To this different Refrangibility of the Rays is owing the Imperfection of the common *Exp.* 289. *refracting* Teleſcope, as will be but too eaſy to experiment.

HENCE alſo Objects of any of the ſimple Colours, 290. though contiguous to each other, yet, if view'd through a Priſm, appear ſeparated, and at a diſtance from one another: And thoſe Objects will have their Images form'd by a Lens at very different Diſtances in its Axis, eſpecially in Experiments of the deepeſt *Red*, and *Violet*, or *Blue Colours*; as a Card painted half with *Carmine*, and half with *Ultramarine*, made deeper with a little *Indigo*.

SIR *Iſaac Newton* found, by a very curious and convincing Experiment, that the Rays of Light were as *Exp.* 291. variouſly reflexible as refrangible; and that thoſe which were moſt or leaſt refrangible were alſo moſt or leaſt reflexible: And farther, that Rays of Light were not reflected by impinging on the ſolid Parts or Corpuſcles of Bodies, and rebounding from thence like a *Tennis-Ball*, but from ſome other Principle depending on the Size of the Particles of Light, and the Thickneſs or Denſity of the Particles of the Body reflecting it, which are all of them, in the moſt opake Bodies, tranſparent in themſelves, as is eaſy to be ſhewn in the thin *Lamellæ* or *Exp.* 292. Plates, of which an Oyſter-Shell doth conſiſt.

IT will be thought very ſtrange to aſſert, that a rare Medium is more impervious to the Rays of Light than a denſer one; and yet nothing is more certain, or eaſier proved *Exp.* 293. by Experiment: For Example, a Beam of Light is much more copiouſly reflected from the ſecond Surface of a Piece of Glaſs when contiguous to the *Air*, than when it touches *Water*; and ſtill more, if contiguous to *Water*, than when it is contiguous to *Glaſs*; in which Caſe the Rays are totally tranſmitted.

HENCE, wonderful as it may ſeem, 'tis neceſſary, in order that a Body may be tranſparent, that its Subſtance ſhould be very denſe, and its Pores very ſmall; and that Opacity reſults chiefly from the Largeneſs of the Pores of a Body, occaſion'd by its Particles touching in but very few Points: Becauſe, if the Pores of ſuch a Body be fill'd with a Subſtance nearly of the ſame Denſity, it becomes in ſome Degree tranſparent, *Exp.* 294. as *Paper wetted with Water or Oil:* And on the contrary,

trary, *Water blown up into ſmall Bubbles* has its Denſity diminiſhed, and its Poroſity increaſed, and thus becomes opake. *Exp.* 295.

IF the Object-Glaſs of a large Teleſcope be laid with its convex Surface on a plain Glaſs, the Light falling on the thin Portion or Plate of Air contain'd between the Glaſſes will be, at ſeveral Diſtances from the Center, alternately tranſmitted and reflected. In the Center of the Lens, where it touches the Glaſs, it will be tranſmitted, and ſo cauſe a *dark Spot* to appear: At a ſmall Diſtance from thence, all around, the Light will be reflected in various-colour'd Rings: In the next Diſtance it will be tranſmitted, and in the next to that reflected; and ſo on alternately to a conſiderable Diſtance from the central Spot. If we take the Diſtances as the Numbers 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, *&c.* then at the Diſtances 0, 2, 4, 6, 8, 10, *&c.* the Light will be tranſmitted; and at the Diſtances 1, 3, 5, 7, 9, *&c.* it will be reflected in colour'd Rings: And this alternate Diſpoſition of Light to be reflected and refracted, Sir *Iſaac* calls the *Fits of eaſy Reflection*, and *Fits of eaſy Tranſmiſſion*. *Exp.* 296.

As Light, falling upon this thin Plate of Air between the Glaſſes, is variouſly diſpoſed to be *reflected* or *tranſmitted*, according to the ſeveral Degrees of Thickneſs; ſo when it falls on the Surface of natural Bodies, it is as variouſly reflected from the Pores of Air of different Thickneſſes in thoſe Bodies; and according to the different Texture of Bodies, and Magnitude of the Particles of Light, it will be either tranſmitted wholly, or in part; and that which is reflected will be *of all one Sort of Rays*, or of *ſeveral Sorts promiſcuouſly and unequally*, or of *all Sorts equally*. Whence it will follow, (1.) If the Light be wholly tranſmitted, the Body will appear *Black*, which is the Abſence of all colour'd Light. (2.) If the Light reflected from Bodies be all of one Sort, that Body will appear all of one Colour, which will be moſt ſimple and intenſely *Exp.* 297. 298.

tenſely deep. (3.) If the Rays are promiſcuouſly reflected, but one Sort more than the reſt, the Body will appear of the Colour proper to that Sort of Ray, but it will be not ſo pure and ſtrong as before. *Exp.* 299. (4.) If three or four Sorts of Rays are promiſcuouſly reflected more than the reſt, the Colour of the Body will be a Mix'd or Compound, inclining to the Tint of the moſt predominant Colour. 300. (5.) When all Sorts of Rays are equally reflected from Bodies, thoſe Bodies appear *White*, or of the Colour of the Sun's Light. 301. (6.) Where there is no Light at all incident on Bodies, thoſe Bodies can have no Colour, which is a Property of the Rays of Light only. 302.

LET BNFG be a ſpherical Drop of falling Rain, and AN a Ray of the Sun falling upon it in the Point N, *F.* XXXV. which Ray ſuppoſe refracted to F, from thence reflected to G, and there again refracted in the Direction GR to the Eye of a Spectator; and let IG be perpendicular to the Point G: Then will the Beam, by its Refraction at G, be ſeparated into its ſeveral Sorts of Rays, which will paint their reſpective Colours in that Part of the Drop; of which that next the Perpendicular IG will be *red*, as being leaſt refracted, and the reſt in Order above it. Now it is found by Computation, that the greateſt Angle S*e*O, or EOP, (drawing OP parallel to SE) under which the moſt refrangible Rays can come to the Eye of a Spectator at O, is 40 Deg. 17 Minutes; and that the greateſt Angle FOP, under which the leaſt refrangible Rays come to the Eye at O, is 42 Deg. 2 Minutes. *Fig.* XXXVI. And ſo all the Particles of Water within the Difference of thoſe two Angles EF will exhibit ſeverally the various Colours of the Priſm, and conſtitute the *interior Bow* in the Cloud.

IF the Beam go not out of the *Drop* at G, but is reflected (a ſecond time) to H, and is there refracted in the Direction HS, making the Angle SYA with the incident Ray AN, it will paint on the Part H the ſeveral Colours of Light, but in an inverſe Order to the former, and more faint, by reaſon of the Rays loſt by the *ſecond Reflection*. It has been found alſo, that the leaſt Angle SGO, or GOP, under which the leaſt refrangible Rays can come to the Eye at O, after two Reflections and two Refractions, is 50 Deg. 57 Minutes; and the leaſt Angle HOP, under which the moſt refrangible Rays can come to the Eye in this Caſe, is 54 Deg. 7 Minutes. Whence all the Colours of the *exterior Bow* will be form'd in the Drops from G to H, which is the Breadth of this Bow, *viz.* 3 Deg. 10 Minutes; whereas the Breadth of the other, *viz.* EF, is but 1 Deg. 45 Min. and the Diſtance between the Bows, *viz.* FG, is 8 Deg. 55 Min. And ſuch would be the Meaſures of the Bows, were the Sun but a *Point*; but ſince his Body ſubtends an Angle of half a Degree, it is evident, by ſo much each Bow will be increaſed, and their Diſtance diminiſh'd. All which will be illuſtrated by Experiments. *Exp.* 303, 304, 305.

HALO's are form'd by Rays of Light coming to the Eye after two Refractions through *Drops of Rain*, or *ſpherical Hail-ſtones*; which Light ought to be ſtrongeſt at the Diſtance of about 26 Degrees from the Sun or Moon, or ſomewhat leſs, if the ſaid Hail-ſtones be a little flatted, as often they are. Theſe *Halo's*, if the Hail be duly figur'd, will be colour'd, and muſt then appear *red* within by the leaſt refrangible Rays, and *blue* without by the moſt refrangible ones.

THE reaſon why there is always a determinate Angle for exhibiting the *Bows*, or *Halo's*, is becauſe there is but one particular Point N in all the Part of the Drop between B and L, where the Rays AN can enter, ſo that after a ſecond Refraction at F for *Halo's*, or Reflection at F and G for the *Bows*, there can enough go out together at G or H, to form a ſtrong and diſtinct Image of the Sun; which Rays, therefore, entering at the Point N are call'd *efficacious Rays*, to diſtinguiſh them from the reſt which are ineffectual.

LECTURE IX, X.

OPTICS.

WE are now arrived to that Part of Natural Philoſophy which treats of *Viſion*, and the various Phænomena of viſible Objects, by Rays of Light reflected from Mirrours, and tranſmitted through Lenſes, which conſtitute the Subject of the moſt delightful Science of OPTICS.

THE principal Things here to be conſider'd are, Firſt, *the Rays of Light*; Secondly, *the Glaſſes by which they are reflected and refracted*; Thirdly, *the Theorems or Laws relating to the Formation of the Images of Objects thereby*; Fourthly, *the Nature of Viſion, and Structure of the Eye*; and Fifthly, *the Structure and Uſe of the principal Optical Inſtruments.*

THE *Rays of Light* are diſtinguiſhed into three Sorts, *viz. Parallel*, *Converging*, and *Diverging Rays*. *Parallel Rays* are ſuch as in their Progreſs keep always an equal Diſtance from each other, as ABDC; ſuch as are the Sun's Rays, in their natural State, with reſpect to Senſe. *Converging Rays* are ſuch as in their Progreſs approach nearer and nearer to each other, all of them tending towards a certain Point F, where they all unite; as the Rays of the Sun collected by a Glaſs, as CDF. *Diverging Rays* are thoſe which proceed from a Point, as F, and in their Progreſs recede from one another towards the Parts GE. *Exp.* 306. *Fi.* XXXVII.

THE Point F, where the Rays are collected, is call'd *Exp.* 307. the *Focus*, or Burning-Point, becauſe there the Sun's Rays, being united within a very ſmall Compaſs or Circle, are greatly conſtipated and condenſed, by which means their Action or Heat is proportionably increaſed, and therefore Objects poſited in that Point will be greatly heated, burnt, or melted.

OF GLASSES there are two Kinds, *viz. Mirrours*, and *Lenſes.* A *Mirrour* or *Speculum* is that, which from one poliſh'd Surface reflects the Rays of Light; and theſe are either *Convex*, *Concave*, or *Plane*, as will be ſhewn. A *Lens* is any tranſparent or diaphanous Body, as *Glaſs*, *Cryſtal*, *Water*, &c. through which the Rays of Light do freely paſs, and is of a proper Form to collect or diſperſe them. Of theſe there are ſeveral Species, as a *Plane Lens*, a *Plano-Convex*, *Plano-Concave*, *Double-Convex*, *Double-Concave*, and *Meniſcus*.

I SHALL now conſider the different Properties and Effects of theſe Glaſſes in reflecting and refracting the Sun's Light, and forming the Images of Objects: And this all depends *(in Reflection of Light)* on that fundamental Law, *That the Angle of Incidence is equal to the Angle of Reflection.*

LET EH be a concave Mirrour, V its Vertex, and *F.* XXXVIII. C the Center of its Concavity. Let A be a Ray of the Sun's Light incident on the Point E, and draw EC, which will be perpendicular to the Mirrour in the Point E; make the Angle CEF equal to the Angle AEC, then ſhall EF be the reflected Ray. Thus alſo HF will be the reflected Ray of the incident one DH, at an equal Diſtance on the other Side of the Axis BV.

IF now the Points E and H be taken very near the Vertex V, we ſhall have EF, or HF, very nearly equal to FV; but EF $= FC$; therefore $FV = FC = \frac{1}{2} CV$. That is, *Exp.* 308. *the Focal Diſtance* FV *of parallel Rays will be at the Diſtance*

Diſtance of half the Radius CV *of the Concavity of the Mirrour, from the Vertex* V, *in the Axis* BV.

AFTER the ſame manner, a *convex Mirrour* is ſhewn to reflect the Rays AE, DH, into EF, HF, as if they came diverging from a Point F in the Axis CV, which is half the Radius CV diſtant from the Vertex V. But ſince the Rays do not actually come at, or from the Focus *f*, it is call'd the *Imaginary or Virtual Focus.* *Fig.* XXXIX. *Exp.* 309.

PARALLEL Rays falling directly on a *plane Speculum* are reflected back upon themſelves; if they fall obliquely, they are reflected in the ſame Angle, and parallel as they fell. Hence there is no ſuch thing, properly ſpeaking, as a *Focus* belonging to a *plane Speculum*, neither *real* nor *virtual.* 310.

THE Focus F, or *f*, of parallel Rays, is call'd the *Solar Focus*; becauſe in that the Image of the *Sun* is form'd, and of all Objects very remote. But the Focus of any Object ſituated near the Mirrour will have its Diſtance from the Vertex more or leſs than half the Radius: The Rule in all Caſes being as follows: *Exp.* 311.

Multiply the Diſtance of the Object into the Radius of the Mirrour, and divide that Product by the Sum of the Radius and twice the Diſtance of the Object; the Quotient will be the Focal Diſtance of a Convex Mirrour.

AGAIN; for a *Concave Mirrour, the ſame Product of the Radius into the Diſtance of the Object, divided by the Difference of Radius and twice the Diſtance of the Object, will give the Focal Diſtance* VF *or* V*f*. And here we are to obſerve, that as twice the Diſtance of the Object is leſſer or greater than the Radius, ſo the Focus will be poſitive or negative, that is, behind the Glaſs or before it. *Exp.* 312.

THE Image of every Object is form'd in the Focus proper to its Diſtance: And ſince the Writers on *Optics* demonſtrate, that

the Angles under which the Object OB *and its Image*
Fig. XL. IM *are ſeen from the Center or Vertex of the Mirrour*
C *are always equal*; it follows, that the Image IM
Exp. 313. will be always in Proportion to the Object OB, as the Focal Diſtance VF to the Object's Diſtance GV.

THE Poſition of the Object will be always erect at a
314. *poſitive Focus*, or behind the *Speculum*; diminiſhed by a convex, and magnified by a concave one. Hence, ſince a convex has but one, *viz.* an *affirmative Focus*; ſo it can never magnify any Object, howſoever poſited before it.

THE Poſition of the Image in a *negative Focus*, or
Exp. 315. that before the Glaſs, will be ever inverted; and if nearer the Vertex than the Center C, it will be leſs; if farther from it, it will be greater than the Object; but in the Center, it will be equal to the Object, and ſeem to touch it.

THE Image form'd by a *plane Speculum* is erect; large
Exp. 316. as the Life; at the ſame apparent Diſtance behind the Glaſs, as the Object is before it; and on the ſame Side of the Glaſs with the Object. Theſe Properties render this Sort of Mirrour of moſt common Uſe, *viz.* as a LOOKING-GLASS.

IF the Rays fall directly, or nearly ſo, on a plane
Exp. 317. Mirrour, and the Object be opake, there will be but *one ſingle Image form'd*, or at leaſt be viſible; and that by the ſecond Surface of the *Speculum*, and not by the firſt, through which the Rays do moſt of them paſs.

BUT if the Object be luminous, and the Rays fall
Exp. 318. very obliquely on the *Speculum*, there will be more than one Image form'd, to an Eye placed in a proper Poſition to view them. The firſt Image being form'd by the firſt Surface will not be ſo bright as the ſecond, which is form'd by the ſecond Surface. The third, fourth, *&c.* Images are produced by ſeveral Reflections of the Rays between the two Surfaces of the *Speculum*; and ſince ſome Light is loſt by each Reflection, the Images

Images from the ſecond will appear ſtill more faint and obſcure, to the eighth, ninth, or tenth, which can ſcarcely be diſcerned at all.

WE proceed now to *Lenſes*; and here, ſince all Viſion by them is effected by the Refraction of Rays through their Subſtance, it will be too intricate an Affair to ſhew the particular Manner how Rays are collected by them to their ſeveral Focus's: It muſt ſuffice only to ſay, *That parallel Rays are refracted through a plano-convex Lens to a Point or Focus, which is the Diameter of the Sphere of its Convexity diſtant from it:* Exp. 319.

THAT *the ſame Rays are collected by a double and equally convex Lens in a Point which is the Center of the Sphere of its Convexity:* Exp. 320.

THAT *parallel Rays are refracted through a plano-concave Lens in ſuch a manner, as though they came from a Point diſtant from it by the Diameter of its Concavity:* 321.

AND *that the ſame Rays are refracted through a double and equally concave Lens, in ſuch manner as though they proceeded from a Point which is the Center of the Concavity.* 322.

AND in caſe of a double and equally convex Lens, we have this general Rule for finding the *Focus* of Rays univerſally, be the Diſtance of the Object and Radius of Convexity what it will, *viz.*

Multiply the Diſtance of the Object by the Radius of Convexity, and divide that Product by the Difference of the ſaid Diſtance and Radius; the Quotient will be the Diſtance of the Focus requir'd.

HENCE, if the Diſtance of the Object be greater than the Radius, the Focus will be *affirmative*, or behind the Lens; and the Image will be inverted, and diminiſh'd in Proportion of its Diſtance to the Diſtance of the Object. Exp. 323.

AGAIN; if the Diſtance of the Object be leſs than Exp. 324. the Radius, the Focus will be *negative*, or on the ſame Side of the Lens as the Object; and the Image will be magnified, and in an erect Poſition.

IF the Diſtance be equal to the Radius, the Focus Exp. 325. will be at an infinite Diſtance; that is, the Rays, after Refraction, will proceed parallel, and will therefore enlighten Bodies at a vaſt Diſtance. Hence the Contrivance of the *Dark Lanthorn* for this Purpoſe.

LASTLY: If the Diſtance of the Object be equal to Exp. 326. twice the Radius, then will the Diſtance of the Focus and Image be equal to the Diſtance of the Object; and conſequently the Image will be equal in Magnitude to the Object, but inverted. Hence the Uſe of theſe Lenſes to Painters, and Draught-Men in general, who have often Occaſion for the Images of Objects as large as the Life, to delineate or draw from.

As to *Plano-concaves*, they, having no real Focus, Exp. 327. form no Images of Objects; ſo that we ſhall paſs them to proceed to the Structure of the Eye, the Manner of performing Viſion therein, the ſeveral Defects thereof, and how remedied by Glaſſes; which will be illuſtrated by the Diſſection of a *natural Eye*, and exemplified by an *artificial one*.

THE *Eye* is the *noble Organ of Sight or Viſion:* It conſiſts of various Coats and Humours, of which there are Three Exp. 328. remarkable, *viz.* (1.) The *Aqueous or Watry Humour*, which lies immediately under the *Cornea*, and makes 329. the Eye globular before. (2.) The *Vitreous Humour*, which is by much the greateſt Quantity, filling the Cavity of the Eye, and giving it the Form of a Globe or 330. Sphere. (3.) The *Cryſtalline Humour*, ſituated between the other two, near the Fore-part of the Eye, and is the immediate Inſtrument of Sight; for being of a lenticular Form, it converges the Rays, which paſs through the Pupil, to a Focus on the Bottom of the Eye, where the Images of external Objects are by that means form'd and repreſented.

OVER all the Bottom of the Eye is ſpread a very fine and curious Membrane, call'd the *Retina*, which is an Expanſion of the *Optic Nerve*; upon which the Images of Objects being painted and impreſs'd, they are by that means convey'd to the *Common Senſory* in the Brain, where the Mind views and contemplates their Ideas; but this in a Manner too myſterious and abſtruſe for us to underſtand. *Exp.* 331.

THE *Cryſtalline Humour* is of ſuch a Convexity, that in a ſound State of the Eye its Focus falls preciſely on the *Retina*, and there paints the Objects; and therefore Viſion is not diſtinct, unleſs by Rays which are parallel, or nearly ſo; for thoſe only will have their Focus at the Bottom of the Eye: Now Rays proceeding from any Point more than 6 Inches diſtant from the Eye, will, when they enter the Pupil, be very nearly co-incident with parallel Rays; and therefore to a ſound Eye diſtinct Viſion cannot be effected at leſs than 6 or 8 Inches Diſtance, as is evident to any who tries the Experiment. *Exp.* 332.

SINCE then there is a certain and determinate Degree of Convexity in the *Cornea* and *Cryſtalline Humour*, for forming the Images of Objects on the *Retina*; if it happens that the Convexity of thoſe Parts ſhould be more or leſs than juſt, the Focus of Rays will fall ſhort of, or beyond the *Retina*, and in either Caſe will cauſe indiſtinct Viſion. The firſt is the Caſe of ſhort-ſighted or *purblind* People, the latter of the *Aged*.

A *purblind Perſon*, having the Convexity of the Eye and Cryſtalline Humour too great, will have the Rays united in a Point before they reach the Bottom of the Eye, and conſequently the Images of Objects will be form'd, not upon the *Retina*, (as they ſhould be) but above it in the Glaſſy Humour, and therefore will appear indiſtinct or confuſed. *Exp.* 333.

THIS Defect of the Eye is remedied two Ways, *viz.* *Exp.* 334. (1.) By diminiſhing the Diſtance between the Object and the Eye; for by leſſening the Diſtance of the Object, the Diſtance of the Focus and Image will be increaſed, till it falls on the *Retina*, and appears diſtinct. (2.) By *Exp.* 335. applying a concave Glaſs to the Eye; for ſuch a Glaſs makes the Rays paſs more diverging to the Eye, in which Caſe the Diſtance of the Focus will be alſo enlarged, and thrown upon the *Retina*, where diſtinct Viſion will enſue.

HENCE the Uſe of *Concave Spectacles:* And the *Myops* *Exp.* 336. or purblind Perſon, who uſes them, has the three following Peculiarities, *viz.* (1.) To him Objects appear nearer than they really are, or do appear to a ſound Eye. (2.) The Objects appear leſs bright, or more obſcure, to them than to other People, becauſe a leſs Quantity of Rays of Light enter the Pupil. (3.) Their Eyes grow better with Age; for whereas the Fault is too great a Convexity of the Eye, the *Aqueous Humour*, and alſo the *Cryſtalline*, waſting with Age will grow flatter, and therefore more fit to view diſtant Objects.

THE other Defect of the Eyes ariſes from a quite *Exp.* 337. contrary Cauſe, *viz.* the *Cornea* and *Cryſtalline Humour* being too flat, as is generally the Caſe of an old Eye. This Defect is remedied by *Convex Lenſes*, ſuch as are the common *Spectacles*, and *Reading Glaſſes*. For ſince the Rays, in theſe Eyes, go beyond the Bottom of the Eye, before they come to a Focus, or form the Image; a convex Glaſs will make the Rays fall more converging to the Pupil, and on the Humours, by which means the Focal Diſtance will be ſhorten'd, and adjuſted to the *Retina*; where diſtinct Viſion of Objects will then be effected.

BY convex Spectacles Objects appear *more bright*, be- *Exp.* 338. cauſe they collect a greater Quantity of Rays on the Pupil. And they appear at a greater Diſtance than they

THE
Pocket Reflecting
Microscope
With a Micrometer.

BY

Benj: Martin

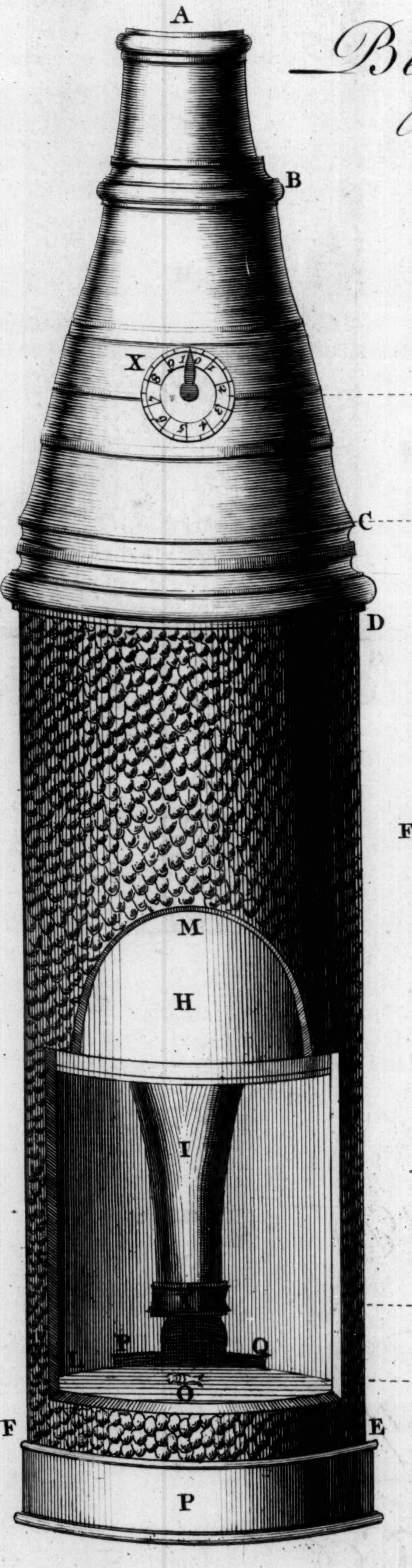


Fig. I.

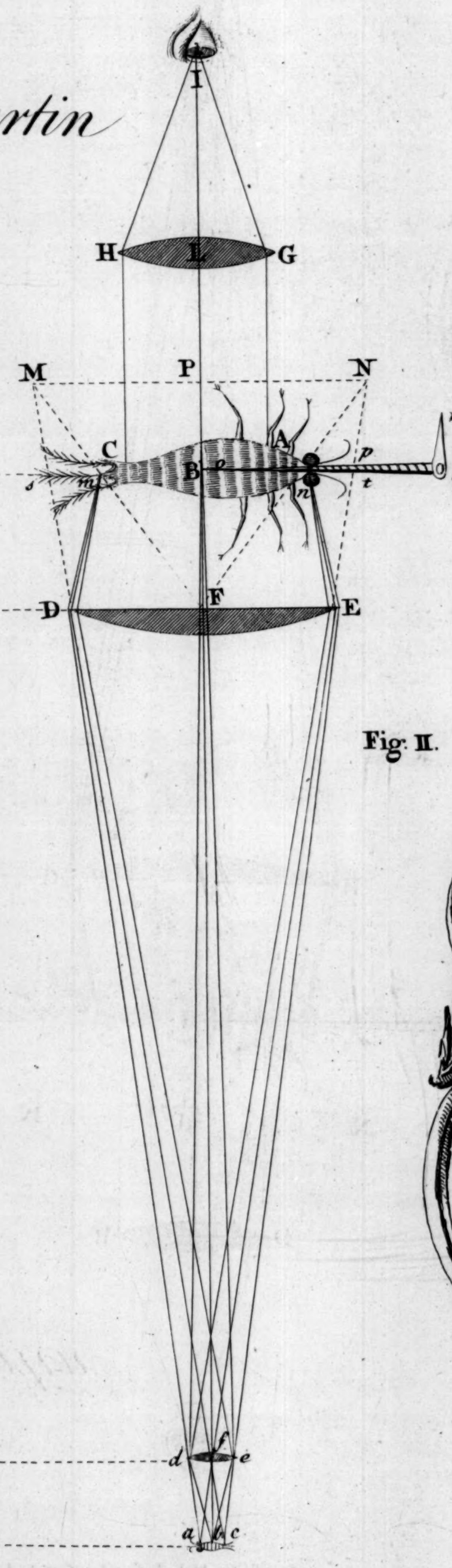
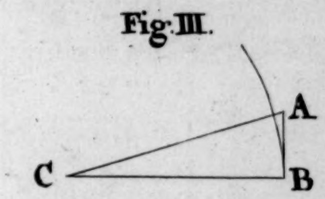
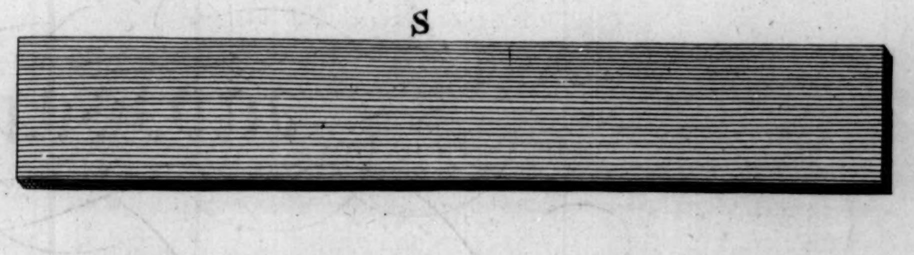


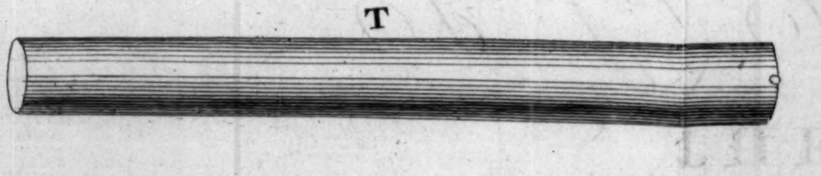
Fig. II.

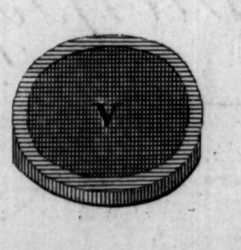
These
Microſcopes
are Sold by
J.ⁿ Newbery
Bookseller
in
Reading Berks.

Fig. III.









Eman: Bowen Sculp.

they are; for the nearer the Rays approach to parallel ones, the more diſtant the Point will be to which they tend.

I HAVE already obſerved, that if the Object be placed nigher to the convex Glaſs than its Focus, it will appear erect and magnified; which makes them of ſuch general Uſe as *Reading Glaſſes.* *Exp.* 339.

IF an Object be placed in the Focus of a convex Lens, the Rays which proceed from it, after they have paſs'd through the Glaſs, will proceed parallel; and therefore an Eye placed any where in the Axis will have the moſt diſtinct View of the Object poſſible; and if it be a Lens of a ſmall Focal Diſtance, then will the Object appear as much larger as it is nearer, than when you view it with the naked Eye. And hence their Uſe as *Single Microſcopes:* To give an Inſtance of which, ſuppoſe the Focal Diſtance of a Lens were one Tenth of an Inch, then will the Diameter or Length of an Object appear 60 times larger than to the naked Eye at ſix Inches Diſtance: Alſo the Superficies of an Object will be 3600 times larger; and the whole Magnitude or Bulk will be 216000 times larger than to the naked Eye it will appear at the abovesaid Diſtance. 340. *Exp.* 341.

COMPOUND Microſcopes, eſpecially the common Sort, are conſtructed with three Glaſſes, *viz.* the Object-Lens *de*, and two Eye-Glaſſes DE and GH. The Object *abc* being placed at a little more than the Focal Diſtance from the Lens *de*, will have its Image form'd at a greater Diſtance on the other Side, and proportionably large, as at MN; which large Image is contracted into one ABC ſomewhat leſs, by the lower Eye-Glaſs DE; and this Image is view'd by the Eye through the upper Eye-Glaſs GH; where it alſo diſtinctly views the MICROMETER *opq*, paſſing over a minute Part of the Image in meaſuring it. But what is farther neceſſary in the Theory and Structure of theſe Microſcopes may be found *Exp.* 342. *Exp.* 343.

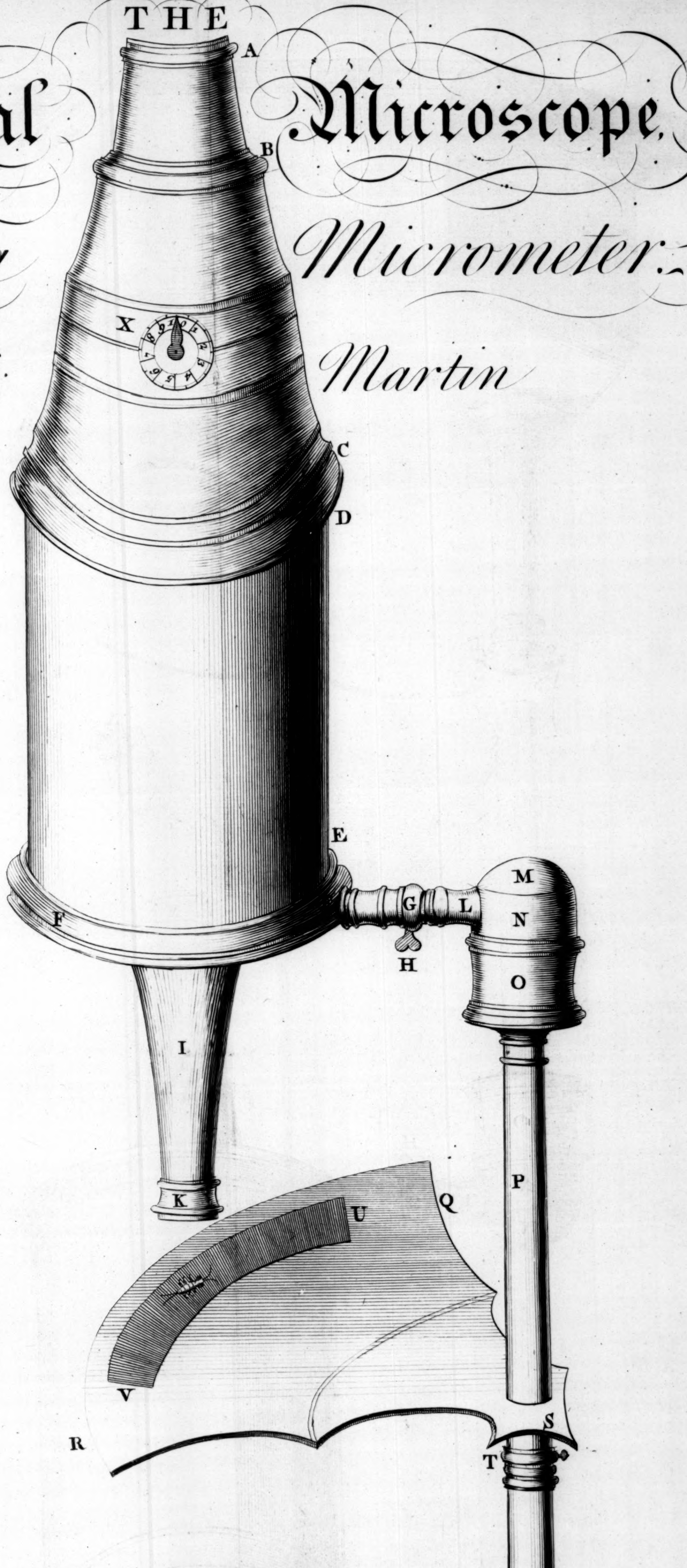
found in my *Micrographia Nova*, together with a large Account of all Kinds of *Microſcopic Objects*, and a Deſcription of the *Solar Microſcope*. Yet, that the Reader may have an Idea of the *two new Forms* of Microſcopes deſcribed in that Book, I have here annex'd the Plates, *viz.* of the POCKET and UNIVERSAL MICROSCOPE reſpectively.

THE TELESCOPE is of two Sorts, *viz. Dioptric*, or *Refracting*; or *Cata-Dioptric*, by *Reflection and Refraction* conjointly. A *refracting Teleſcope* conſiſts of an Object-Glaſs xz, by *Fig.* XLI. which the Image fd of an Object OB, at a diſtance, is form'd in the Focus e of the ſaid Glaſs, and in an *inverted Poſition*. This Image may be view'd by a ſingle *Exp.* 344. Lens ab, placed at its Focal Diſtance, as is uſually done for viewing the heavenly Bodies, becauſe in them we 345. regard not the Poſition: But for viewing Objects near us, whoſe Image we would have erect, we muſt for that Purpoſe add a ſecond Lens pq, at double its Focal Diſtance from the other, that the Rays which come from ab may croſs each other in the Focus O, in order to erect the Image gn, which it will form in its own Focus m, becauſe the Rays come parallel from the firſt Lens ab. Laſtly, a third Lens ic is added, to view that ſecondary Image gn. Theſe three Lenſes, or Eye-*Exp.* 346. Glaſſes, are uſually of the ſame Size and Focal Length; and the Power of magnifying is always *as the Focal Length of the Object-Glaſs* ew *divided by the Focal Length of the Eye-Glaſs* lm *or* he. For inſtance: Suppoſe $ew = 10$ Feet or 120 Inches, and he or $lm = 3$ Inches; then will the Length of the Object appear to the Eye through ſuch a Teleſcope 40 times larger than to the naked Eye; and its Surface will be magnified 1600 times, and its Bulk or Solidity 64000 times.

IF inſtead of a *convex Eye-Glaſs* we ſhould uſe a *Exp.* 347. *concave* one of the ſame Focal Length, it would repreſent the Object erect, equally magnified, and more diſtinct

THE Universal Microscope, with a Micrometer.

By Benj: Martin



These
Microſcopes
are Sold by
J. Newbery
Bookseller
in
Reading Berks.

Eman: Bowen Sculp.

ſtinct and bright; but the Diſadvantage of this Glaſs is, that it admits of but a ſmall *Area*, or *Field of View*, and therefore not to be uſed when we would ſee much of an Object, or take in a great Scope; but it is uſed to great Advantage in viewing the *Planets* and their *Satellites*, *Saturn's Ring*, *Jupiter's Belts*, &c. This is call'd the *Galilean Teleſcope*, from *Galileo*, the Inventor, and is the firſt Sort of Teleſcope ever made.

THE *Cata-dioptric* or *Reflecting Teleſcope* is the moſt noble and uſeful of all others; the *Mechaniſm* whereof *Fig.* XLII. is as follows: ABEH is the large Tube or Body of the Inſtrument, in which BE is a large reflecting Mirrour, *Exp.* 348. with a Hole in the Middle CD. This Mirrour receives the Rays *ac*, *bd*, coming from the Object at a diſtance, and reflects them converging to its Focus *e*, where they croſs each other, and form the inverted Image IM. *xy* is a ſmall concave Mirrour, whoſe Focus is at *f*, at a ſmall Diſtance from the Image. By this means the Rays coming from the Image are re- *Exp.* 349. flected back through the central Hole CD of the large Mirrour, where they fall on the plano-convex Lens 350. WX, and are by it converged to a Focus, and there form a ſecond Image RS, very large and erect, which is view'd by a *Meniſcus Eye-Glaſs* YZ by the Eye at 351. P, through a very ſmall Hole in the End of the Eye-Piece YCDZ.

IF the firſt Lens WX were taken away, the Image would be form'd ſomewhat larger at *Mg*; but the *A-* 352. *rea*, or *Scope*, would be leſs, and therefore the View not ſo pleaſant. At TV is placed a circular Piece of Braſs, with a Hole of a proper Size to circumſcribe the Image, and cut off all ſuperfluous or extraneous Rays, that ſo the Object may appear as diſtinct as poſſible.

As the Image is form'd by Reflection, the Rays of every Sort will be united nearly in one Point, and will therefore admit of

an

an Eye-Glaſs Y Z of a deep Charge, or ſmall Focal Di- *Exp.* 353. ſtance; and ſo the Power of magnifying will be proportionally greater; for it will be in a Proportion compounded of $\frac{Qe}{eG}$ and $\frac{Gk}{kt}$, if only one Eye-Glaſs Yz be uſed. Thus, in Numbers, ſuppoſe $Qe = 12$ Inches, $eG = 3,5$; $Gk = 18$, and $kt = 1$; then will $\frac{12}{3,5} \times \frac{18}{1} = \frac{176}{3,5} = 50$ nearly; whence by ſuch a Teleſcope the Length of an Object will be magnified 50 times, the Surface 2500 times, and the Solidity 125000 times; yet the Teleſcope not above 20 Inches long; an Effect equal to that of a refracting Teleſcope 16 Feet in Length.

As to the *Camera Obſcura*, and *Magic Lanthorn*, *Exp.* 354. they both perform their Effects by a ſingle Lens; the former being only the Object-Glaſs of a long Teleſcope applied in a *Scioptric Ball* to the Hole of a Window-Shutter, in a darken'd Room; which gives a lively Picture of all the Objects which lie before it, in true Perſpective, but in an *inverted Poſition*, on a white Sheet or Plane held at the Focal Diſtance of the ſaid Glaſs: And on the other hand, the *Magic Lant-* *Exp.* 355. *horn* is only a large convex Lens, with a ſhort Focal Diſtance, which by being placed at a proper Diſtance from ſmall tranſparent-colour'd Pictures or Figures, forms a large and ſurprizing Image thereof at a great Diſtance; in order to which, it is neceſſary to illuminate them very ſtrongly with the Light of the Candle thrown on them by another *very large and very convex Lens.*

THE *Solar Microſcope* is of the ſame Kind with the *Exp.* 356. *Magic Lanthorn*; only here the Objects are very ſmall, and ſtrongly enlighten'd by the Sun through a concave Lens; they are alſo magnified by a ſmall Lens, of a very ſhort Focal Diſtance, that the Images may be thrown large and diſtinctly on the oppoſite Wall of a darken'd Room: Which, if well perform'd,

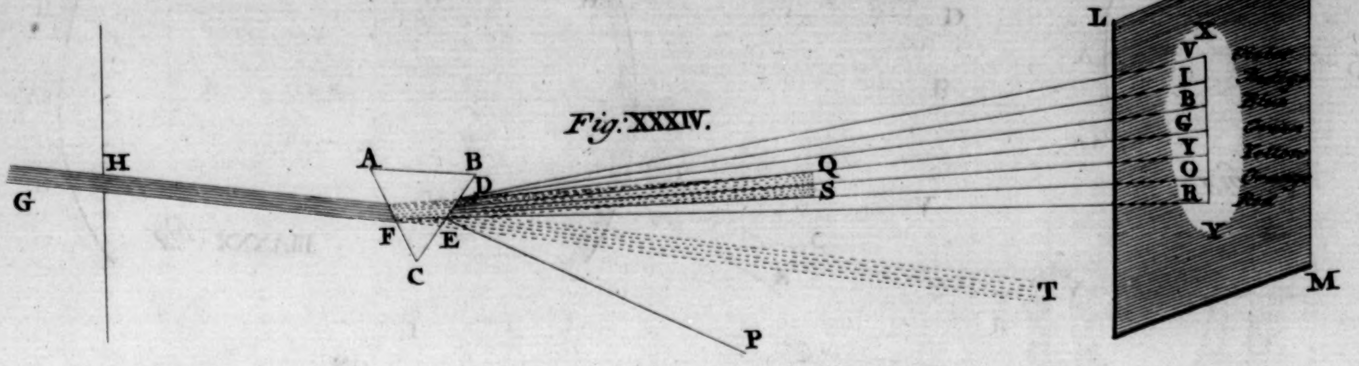


Fig: XXXIV.

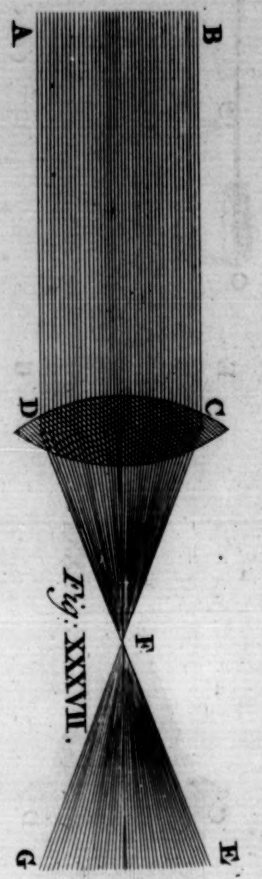


Fig: XXXVII.

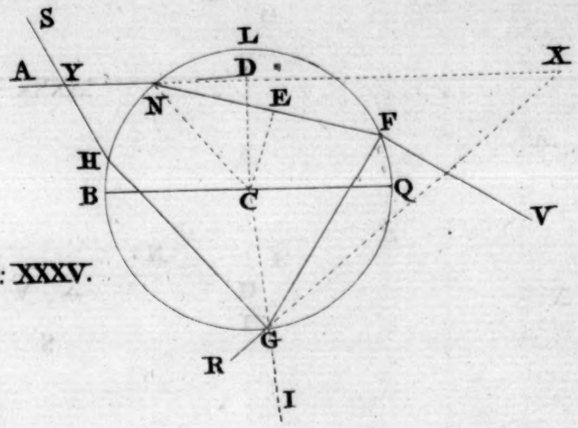


Fig: XXXV.

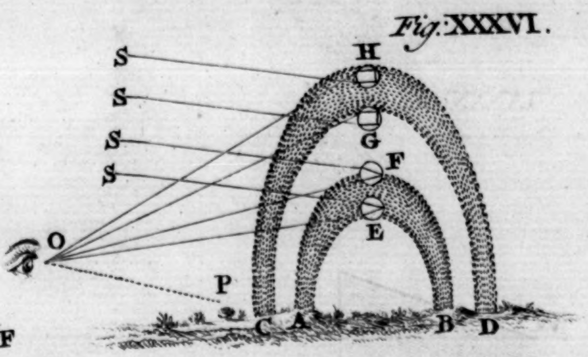


Fig: XXXVI.

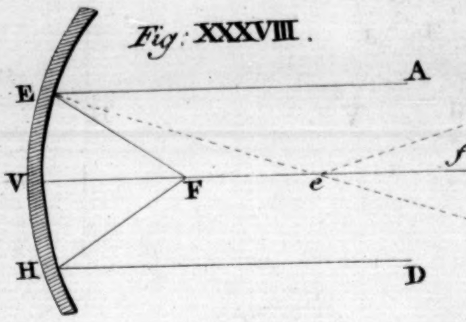


Fig: XXXVIII.

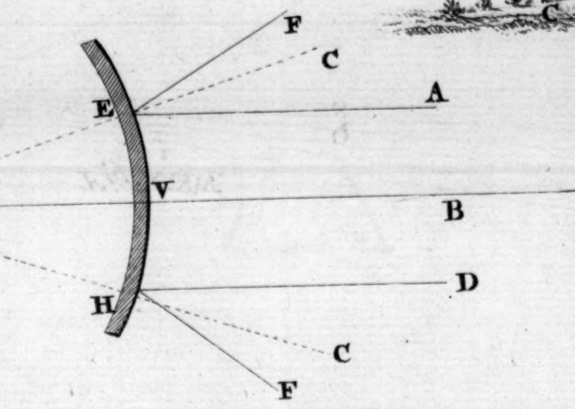


Fig: XXXIX.

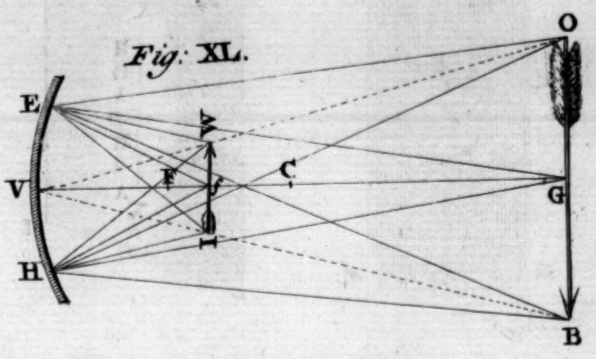


Fig: XL.

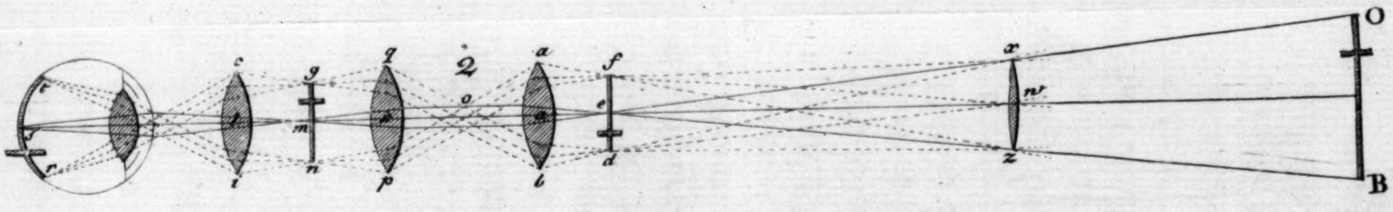


Fig: XLI.

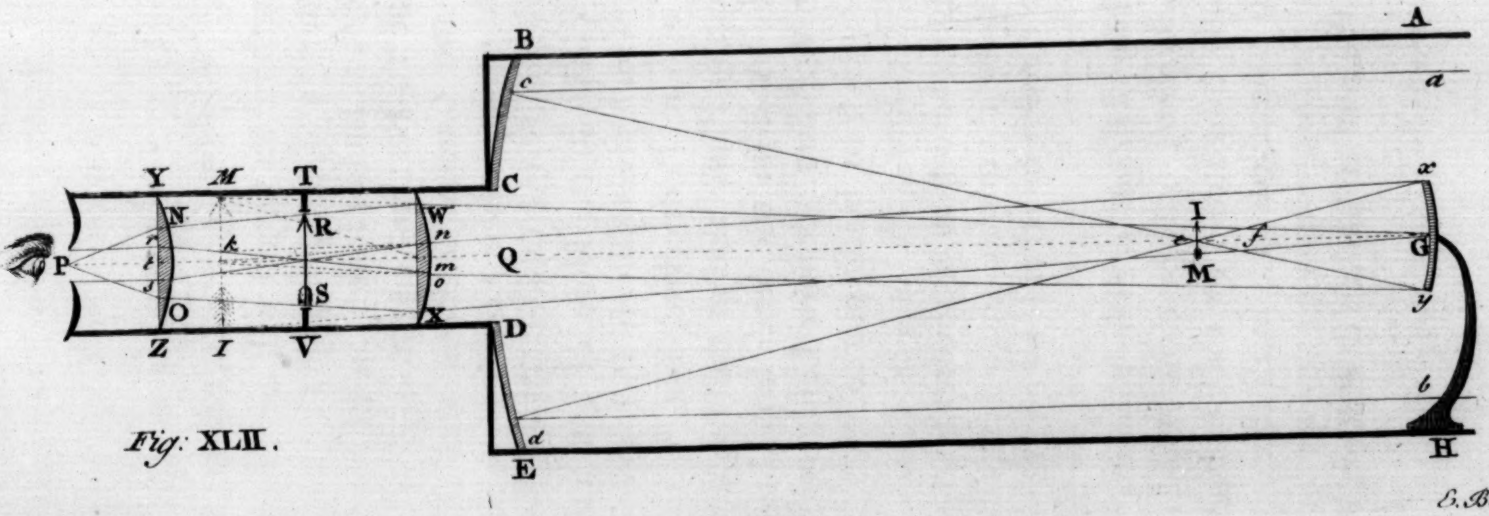


Fig: XLII.

E. Bowen sc.

perform'd, is one of the moſt exquiſitely curious and moſt delightfully ſurprizing Effects that are poſſible to be produced by any Optical Inſtrument whatſoever.

LECTURE XI.

The COPERNICAN *or* SOLAR SYSTEM *explain'd by the* ORRERY *and* COMETARIUM.

I SHALL in this Lecture endeavour to exhibit to you a *juſt and natural Idea of the Mundane or Solar Syſtem*, that is, the Syſtem of the World; conſiſting of the *Sun*; the *Primary Planets*, and their *Secondaries*, or *Moons*; the *Comets*; and the *Fixed Stars*; according to the Hypotheſis of *Pythagoras* among the Ancients, and revived by *Copernicus:* Which Syſtem is fully proved, and eſtabliſh'd on the juſteſt Reaſoning, and Phyſical and Geometrical Concluſions, by all our modern Aſtronomers.

THE moſt celebrated Hypotheſes, or Syſtems of the World, are three, *viz.* (1.) The *Ptolomean*, invented by *Ptolomy*, an antient *Egyptian* Philoſopher, which aſſigns ſuch Poſitions and Motions to the heavenly Bodies, as they appear to the Senſes to have. (2.) The *Tychonic Syſtem*, or that of the Noble *Daniſh* Philoſopher, *Tycho Brahe.* (3.) The *Pythagorean*, *Copernican*, or *Solar Syſtem*, above-mention'd. Of all which in Order.

THE *Ptolomean Syſtem* ſuppoſes the Earth immoveably fix'd in the Center, not of the *World* only, but of the *Univerſe*; and that the *Sun*, the *Moon*, the *Planets*, and *Stars*, all moved about it from *Eaſt* to *Weſt* once in twenty-four Hours, in the Order following, *viz.* the *Moon*, *Mercury*, *Venus*, the *Sun*, *Mars*, *Jupiter*,

ter, *Saturn*, the *Fix'd Stars*; and, above all, the Figment of their *Primum Mobile*, or the Sphere which gave Motion to all the reſt. But this was too groſs, and abſurd, to be received by any learned Philoſopher, after the Diſcoveries by Obſervations and Inſtruments which acquaint us with divers Phænomena of the heavenly Bodies, altogether inconſiſtent with, and, in ſome Things, exactly contradictory to, ſuch an Hypotheſis; as will be ſhewn by the Arguments adduced to prove the Truth of the *Copernican Syſtem*.

THE *Tychonic Syſtem* ſuppoſed the Earth in the Center of the World, that is, of the Firmament of Stars, and alſo of the Orbits of the Sun and Moon; but at the ſame time it made the Sun the Center of the Planetary Motions, *viz.* of the Orbits of *Mercury*, *Venus*, *Mars*, *Jupiter*, and *Saturn*. Thus the Sun, with all its Planets, was made to revolve about the Earth once a Year, to ſolve the *Phænomena* ariſing from the *annual Motion*; and the Earth about its Axis from Weſt to Eaſt once in 24 Hours, to account for thoſe of the *diurnal Motion*. But this *Hypotheſis* is ſo monſtrouſly abſurd, and contrary to the great Simplicity of Nature, and in ſome reſpects even contradictory to Appearances, that it obtain'd but little Credit, and ſoon gave way to

THE *Copernican Syſtem* of the World, which ſuppoſes the Sun to poſſeſs the central Part; and that about it revolve the *Planets* and *Comets* in different Periods of Time, and at different Diſtances therefrom, in the Order following, *viz.*

I. MERCURY, at the Diſtance of about 32 Millions of Miles, revolves about the Sun in the Space of 87 Days, 23 Hours, and 16 Minutes.

II. VENUS, at the Diſtance of 59 Millions of Miles, in 224 Days, 16 Hours, 49 Minutes.

III. THE EARTH, at the Diſtance of about 82 Millions of Miles, in 365 d. 6 h. 9 m. or *Sydereal* Year.

IV. MARS, at the Diſtance of 123 Millions of Miles, in 686 d. 23 h. 27 m. or 1 Year, 321 d. 17 h. 18 m.

V. JUPITER, at the Diſtance of 424 Millions of Miles, in 4332 Days, 12 h. 20 m. or almoſt 12 Years.

VI. SATURN, at the Diſtance of 777 Millions of Miles, in 10759 d. 6 h. 36 m. or nearly 30 Years.

VII. THE COMETS, in various and vaſty eccentric Orbits, revolve about the Sun in different Situations and Periods of Time, as repreſented in the Scheme of Mr. *Whiſton*'s Solar Syſtem.

THESE are all the heavenly Bodies yet known to circulate about the Sun, as the Center of their Motions; and among the Planets, there are three which are found to have their *ſecondary Planets*, *Satellites*, or *Moons*, revolving conſtantly about them, as the Centers of their Motions, *viz.*

THE EARTH, which has only *one Moon* revolving about it, in 27 d. 7 h. 43 m. at the mean Diſtance of about 240000 Miles.

JUPITER is obſerved with a Teleſcope to have four *Satellites*, which move about him in the Times and Diſtances following, *viz.*

THE *Firſt* in 1 d. 18 h. 27 m. at the Diſtance of $5\frac{6}{10}$ Semidiameters of *Jupiter*'s Body from his Center, as meaſured with a Micrometer.

THE *Second* in 3 d. 13 h. 13 m. at the Diſtance of 9 Semidiameters.

THE *Third* in 7 d. 3 h. 42 m. at the Diſtance of $14\frac{3}{10}$ Semidiameters.

THE *Fourth* in 16 d. 16 h. 32 m. at the Diſtance of $25\frac{3}{10}$ Semidiameters.

SATURN has *five Moons*; and beſides them a ſtupendous RING ſurrounding his Body, whoſe *Width* and *Diſtance* from *Saturn*'s Body are equal, and computed at upwards of 20000 Miles. The Periodical Times and Diſtances of the *Saturnian* Moons, in Semidiameters of the Ring, are as follow.

THE *Firſt*, or inmoſt, revolves about *Saturn* in 1 d. 21 h. 18 m. at the Diſtance of near 2 Semidiameters of the Ring.

THE *Second* in 2 d. 17 h. 41 m. at the Diſt. of $2\frac{2}{5}$ Semidiameters.

THE *Third* in 4 d. 12 h. 25 m. at the Diſtance of $3\frac{2}{5}$ Semidiameters.

THE *Fourth* in 15 d. 22 h. 41 m. at the Diſtance of 8 Semidiameters.

THE *Fifth* in 70 d. 22 h. 4 m. at the Diſtance of $23\frac{3}{10}$ Semidiameters.

THESE are the conſtituent Parts of the *Solar Syſtem*, which is now received and approved as the only *true Syſtem of the World*, for the following Reaſons.

I. IT is moſt ſimple, and agreeable to the Tenor of Nature in all her Actions; for by the two Motions of the Earth all the *Phænomena* of the Heavens are reſolved, which by other *Hypotheſes* are inexplicable without a great Number of other Motions, contrary to philoſophical Reaſoning by Rule I.

II. IT is more rational to ſuppoſe the Earth moves about the Sun, than that the huge Bodies of the Planets, the ſtupendous Body of the Sun, and the immenſe Firmament of Stars, ſhould all move round the inconſiderable Body of the Earth every twenty-four Hours.

III. THE Earth moving round the Sun is agreeable to that general Harmony, and univerſal Law, which all other moving Bodies of the Syſtem obſerve, viz. *That the Squares of the periodical Times are as the Cubes of the Diſtances:* But if the Sun move about the Earth, that Law is deſtroy'd, and the general Order and Symmetry of Nature interrupted; ſince according to that Law the Sun would be ſo far from revolving about the Earth in 365 Days, that it would require no leſs than 5196 Years to accompliſh one Revolution.

IV. AGAIN: Did the Sun obſerve the univerſal Law, and yet revolve in 365 Days, his Diſtance ought not to be above 310 Semidiameters of the Earth; whereas it is eaſy to prove it is really above 20000 Semidiameters diſtant from us.

V. THE Sun is the Fountain of Light and Heat, which it irradiates through all the Syſtem; and therefore it ought to be placed in the Center, that ſo all the Planets may at all times have it in an uniform and equable Manner: For,

VI. IF the Earth be in the Center, and the Sun and Planets revolve about it, the Planets would then, like the Comets, be ſcorched with Heat when neareſt the Sun, and frozen with Cold in their *Aphelia*, or greateſt Diſtance; which is not to be ſuppoſed.

VII. IF the Sun be placed in the Center of the Syſtem, we have then the rational Hypotheſis of the Planets being all moved about the Sun by the univerſal Law or Power of Gravity ariſing from his vaſt Body; and every thing will anſwer to the Laws of circular Motion, and central Forces: But otherwiſe we are wholly in the dark, and know nothing of the Laws and Operations of Nature.

VIII. BUT happily we are able to give not only *Reaſon*, but *demonſtrative Proofs*, that the Sun does poſſeſs the Center of the Syſtem, and that the Planets move about it at the Diſtance and in the Order above aſſign'd: The *firſt* of which is, That *Mercury* and *Venus* are ever obſerved to have *two Conjunctions* with the Sun, but no *Oppoſition*; which could not happen, unleſs the Orbits of thoſe Planets lay within the Orbit of the Earth.

IX. THE *ſecond* is, That *Mars*, *Jupiter*, and *Saturn*, have each their *Conjunctions* and *Oppoſitions* to the Sun, alternate and ſucceſſively; which could not be, unleſs their Orbits were exterior to the Orbit of the Earth.

X. IN the *third* Place, The *greateſt Elongation* or *Diſtance* of *Mercury* from the Sun is but about 20 Degrees, and that of *Venus* but about 47; which anſwers exactly to their Diſtances in the Syſtem above aſſign'd: But in the *Ptolomean* Syſtem, they might and would ſometimes be ſeen 180 Degrees from the Sun, *viz.* in Oppoſition to him.

XI. FOURTHLY, In this Diſpoſition of the Planets they will all of them be ſometimes much nearer to the Earth than at others; the Conſequence of which is, that their Brightneſs and Splendor, and alſo their *apparent Diameters*, will be proportionally greater at one Time than another: And this we obſerve to be true every Day. Thus the apparent Diameter of *Venus*, when greateſt, is near 66 Minutes, but when leaſt not more than 9 Minutes and a half; of *Mars*, when greateſt, it is 21 Minutes, but when leaſt no more than 2 Minutes and a half; whereas by the *Ptolomean* Hypotheſis they ought always to be equal.

XII. THE *fifth* is, That when the Planets are view'd with a good Teleſcope they appear with *different Phaſes*, or with different Parts of their Bodies enlighten'd. Thus *Venus* is ſometimes *new*, then *horned*, after that *dichotomized*, then *gibbous*, afterwards *full*; and ſo increaſes and decreaſes her Light, in the ſame manner as the Moon, and as the *Copernican Syſtem* requires.

XIII. THE *ſixth* is, That the Planets, all of them, do ſometimes appear *direct* in Motion, ſometimes *retrograde*, and at other times *ſtationary*. Thus *Venus*, as ſhe paſſes from her greateſt Elongation Weſtward to her greateſt Elongation Eaſtward, will appear *direct in Motion*, but *retrograde* as ſhe paſſes from the latter to the former; and when ſhe is in thoſe Points of greateſt Diſtance from the Sun, ſhe ſeems for ſome time *ſtationary:* All which is neceſſary upon the *Copernican Hypotheſis*, but cannot happen in any other.

XIV. THE *ſeventh* is, That the Bodies of *Mercury* and *Venus*, in their lower Conjunctions with the Sun, are *hid behind the Sun's Body*; and, in the upper Conjunctions, are ſeen to paſs over the Sun's Body or Diſk in form of a *black round Spot:* Which is neceſſary in the *Copernican*, but impoſſible in the *Ptolomean* Syſtem.

XV. THE *eighth* is, That the Times in which theſe *Conjunctions*, *Oppoſitions*, *Stations*, and *Retrogradations* of the Planets happen, are not ſuch as they would be, were the Earth at Reſt in its Orbit; but preciſely ſuch as would happen, were the Earth to move, and all the Planets in the Periods above aſſign'd them: And *therefore this, and no other, can be the true Syſtem of the World*; and it will ſtand the eternal Teſt of future Ages, for, MIGHTY IS THE FORCE OF TRUTH, AND SHALL PREVAIL.

BUT though the Planets all move round the Sun in Orbits commonly ſuppoſed *circular*, yet are they not exactly ſo, but *elliptical*, or in form of an ELLIPSIS, which Figure is vulgarly call'd an *Oval*, as ABPD, deſcribed about two Centers S, F, call'd the *Foci*, or *Focal Points* of the Ellipſe. The Point C is the Center; AP the Axis, or longeſt Diameter; and BD the ſhorteſt Diameter: And in one of theſe Focus's, *viz.* S, the Sun is placed, about which the Planet moves in the Orbit ABPD. *Fig.* XLIII.

HENCE, when the Planet is in the Point P, it is neareſt the Sun, which Point is, for that Reaſon, call'd the *Perihelion:* Here, therefore, the Attraction of the Sun is ſtrongeſt, his Light and Heat greateſt, and his apparent Diameter largeſt; and in this Point the Planet muſt conſequently move with the greateſt Velocity. But in the Point A, where the Planet is fartheſt diſtant from the Sun, (for that Reaſon call'd the *Aphelion)* every thing is juſt the reverſe: And in the Points B or D it is in its mean Diſtance from the Sun.

Now though the Planetary Orbits are really *elliptical*, yet is the *Eccentricity* CS, in moſt of them, ſo extremely ſmall, as to be almoſt inſenſible; and therefore their Motions may be look'd upon as *circular*, and as ſuch repreſented in Orreries and Diagrams, without any ſenſible Error.

THE ORRERY is, therefore, an adequate Repreſentation of the TRUE SOLAR SYSTEM, and gives a juſt Idea of the *Number*, *Motions*, *Order*, and *Poſitions* of the heavenly Bodies: But the Proportion of *Magnitude* and *Diſtances* of the Planets is not to be expected from the Orrery, but by Delineation, as in Mr. *Whiſton*'s *Solar Syſtem*; where the ſeveral Orbits of the Planets are laid down in their proportional Diſtances from the Sun; and their

Magnitudes comparatively with each other, and with that of the Sun, expreſs'd by the outmoſt Circle of the Scheme.

THE principal Uſe of the Orrery is to render the Theory of the *Earth* and the *Moon* eaſy and intelligible; and to evidence to our Senſes how all thoſe Appearances happen, which depend on the *annual* or *diurnal Rotation* of the *Earth*, and the *monthly Revolutions* of the *Moon:* As, the Variety of Seaſons, the Viciſſitudes and various Lengths of Days and Nights, the Manner of Solar and Lunar Eclipſes, the various Phaſes of the Moon, *&c.*

IN my *Orrery*, which is of a peculiar and moſt elegant Structure, the *Earth* in its annual Motion paſſes round by a Circle, on which is engraved the *Calendar*, and the *Ecliptic*; and the Plate which carries the Earth about has an Index on the oppoſite Part from the Earth, to ſhew the apparent Place of the Sun in the *Ecliptic*, for every Day of the Year; and one Turn of the Winch carries the Earth once round its Axis, and the ſaid Index over the Space of one Day in the Calendar: So that by this means the true Place of the Earth, and the apparent Place of the Sun, alſo the Place and Phaſes of the Moon, may be readily ſhewn for any Day required.

THE *Orrery-Part*, containing the *Wheel-Work*, is placed within a large and moſt beautiful ARMILLARY SPHERE, which turns about upon its Axis, with a fairly-engraved and ſilver'd Horizon, which is alſo moveable every way upon a moſt elegant Braſs Supporter, with four Legs richly wrought; at the Bottom of which is a noble large ſilver'd Plate, with a Box and NEEDLE, and COMPASS, with the Names of all the *Points* finely engraven in Words at Length. The Circles of the Sphere are as follow.

THE EQUINOCTIAL, which divides the Sphere into two Parts, *viz.* the *Northern* and the *Southern Hemiſphere*; and is ſo call'd, becauſe when the Sun comes to paſs over it, (as it does twice every Year) the *Days and Nights are then equal.* This Circle is divided into 360 Degrees, call'd the *Right Aſcenſion* of the Sun or Stars.

THE ECLIPTIC is that great Circle which repreſents the apparent annual Path of the Sun through the Heavens. It is divided into 12 equal Parts call'd *Signs*, conſiſting of 30 Degrees each; whoſe *Names* and *Characters* are as follows. 1. *Aries*, the Ram, ♈; 2. *Taurus*, the Bull, ♉; 3. *Gemini*, the Twins, ♊; 4. *Cancer*, the Crab, ♋; 5. *Leo*, the Lion, ♌; 6. *Virgo*, the Virgin, ♍; 7. *Libra*, the Scales, ♎; 8. *Scorpio*, the Scorpion, ♏; 9. *Sagittarius*, the Bowman, ♐; 10. *Capricorn*, the horned Goat, ♑; 11. *Aquarius*, the Waterer, ♒; 12. *Piſces*, the Fiſhes, ♓. The *Ecliptic* interſects the *Equinoctial* in the Beginning of *Aries* and *Libra*, in an Angle of 23 Degrees, 29 Minutes. In this Circle the Longitude of the heavenly Bodies is reckon'd. The *Ecliptic* is the Middle of

THE ZODIAC, which is a broad ſilver'd *Zone*, encompaſſing the Sphere to five Degrees on each Side the *Ecliptic*; ſo call'd from the Figures of the ſeveral *Animals*, or *Conſtellations of the Signs*, with which it is adorned and embelliſh'd. This Zone comprehends within it the *Paths* or *Orbits* of all the *Planets*.

THE MERIDIAN is a great Circle paſſing through the *Poles*, and cutting the *Equinoctial* at Right Angles; ſo call'd, becauſe when the Sun is upon any Meridian, it makes the *Meridies*, Mid-Day, or Noon, to all Places under it. Of theſe, there is one call'd

THE GENERAL MERIDIAN, within which the whole Sphere turns, and upon which are engraven the *Degrees of Latitude*, beginning and proceeding each way from the Equinoctial to the Poles. To this Circle the Sphere is ſuſpended; and being moveable within the Horizon, the Sphere may be *elevated* or *rectified for the Latitude of any Place*.

THE HORIZON is that broad ſilver'd Frame, or Circle, which contains the whole Machine, moveable every way within it. It is ſo call'd becauſe it bounds our Sight in the Heavens, and divides the Sphere into *the upper and lower Hemiſphere.* Upon this Circle are curiouſly engraven the *Ecliptic Signs* and the *Calendar*, for readily finding the Sun's Place for any given Day or Time. On this Circle is alſo reckon'd the *Amplitude of the Sun*, &c.

THE Points where the Ecliptic interſects the Equinoctial are call'd the *Equinoctial Points*, or EQUINOXES, becauſe when the Sun is in them, *the Days and Nights are equal.* As the Sun is in one of them in the *Spring*, it is call'd the *Vernal Equinox*; and in the other at *Autumn*, it is call'd the *Autumnal Equinox.*

THE Beginning of *Cancer* and *Capricorn* are call'd the *Solſtitial Points*, or the SOLSTICES; which is as much as to ſay, *the Stations of the Sun*, becauſe when the Sun is in thoſe Points, he ſeems *ſtationary*, or *not to move* for ſome Days: The firſt is the *Summer*, the other the *Winter Solſtice.*

THE Meridians which paſs through the *Points* above-mention'd are call'd the *Equinoctial* and *Solſtitial* COLURES reſpectively. They divide the Sphere into *four Quarters*, in the Middle of the *four Seaſons of the Year.*

THE Leſſer Circles of the Sphere are the TROPICS and POLAR CIRCLES; which are all parallel to the Equinoctial, and are two on either Side. The *Northern Tropic* is that of *Cancer*; the *Southern*, that of *Capricorn*; as paſſing through the Beginning of thoſe Signs. They are diſtant from the Equinoctial 23 Degrees, 29 Minutes, and include that Space or Part of the Sphere which is call'd the *Torrid Zone* on the Terreſtrial Globe, becauſe the Sun is at one Time or other perpendicular over every Part, and extremely torrifies or heats it.

WITHIN 23 Deg. 29 Min. of each Pole lie the *Polar Circles*; of which that about the North Pole is call'd the *Arctic Circle*, becauſe of the Conſtellation of the *Bear* in that Part; and the other about the South Pole, the *Antarctic Circle.* They include thoſe Spaces which are call'd the *Frigid Zones*, by reaſon of the intenſe Cold which reigns in thoſe Regions the greateſt Part of the Year.

Thoſe Spaces which lie between the Tropics and Polar Circles, on either Side, are call'd the *Temperate Zones*, as enjoying a mean or moderate Degree of Heat and Cold.

THE Circles above are eſſential to the Sphere; beſides which there is the *Quadrant of Altitude*, for ſhewing the Height of any Luminary above the Horizon; and a large and moſt beautiful *Horary Circle and Index*, ſhewing the Time correſponding to the Motion of the Sphere: Alſo the *Solar Label*, for fixing the Sun to its proper Place in the *Ecliptic*.

IT is eaſy to conceive, that the Sun will always enlighten *one Half of the Earth*; and that when the Sun is in the Equinoctial, the Circle which terminates *the enlighten'd and darken'd Hemiſpheres* (which is call'd *the Circle of Illumination)* will paſs thro' the *Poles of the Earth*, and alſo divide all the *Parallels of Latitude* into two equal Parts. But ſince the Earth moves not in the Plane of the *Equinoctial*, but that of the *Ecliptic*, the Axis of the Earth will be inclined to that of the *Ecliptic* in an Angle of 23 Deg. 29 Min.; and therefore the *Circle of Illumination* will, at all other Times, divide the *Parallels of Latitude* into two unequal Parts.

Now ſince any Parallel is the Path or Tract which any Place therein deſcribes in one Revolution of the Earth, or 24 Hours; therefore that Part of the Parallel which lies in *the enlighten'd Hemiſphere* will repreſent *the Diurnal Arch*, or *Length of the Day*; and that Part in *the dark Hemiſphere* will be *the Nocturnal Arch*, or *Length of the Night*, in that Parallel of Latitude.

HENCE, when the Orrery is put into Motion, the Earth moving with its Axis always *parallel to itſelf*, yet always *inclined to the Plane of the Ecliptic*, will ſometimes have the *Northern* Parts turn'd more directly to the Sun, and moſt enlighten'd; and at other times the *Southern* Parts will be ſo. Hence various Alterations of *Heat and Cold*, and *Length of Days and Nights*, will enſue in the Courſe of the Revolution of the Earth about the

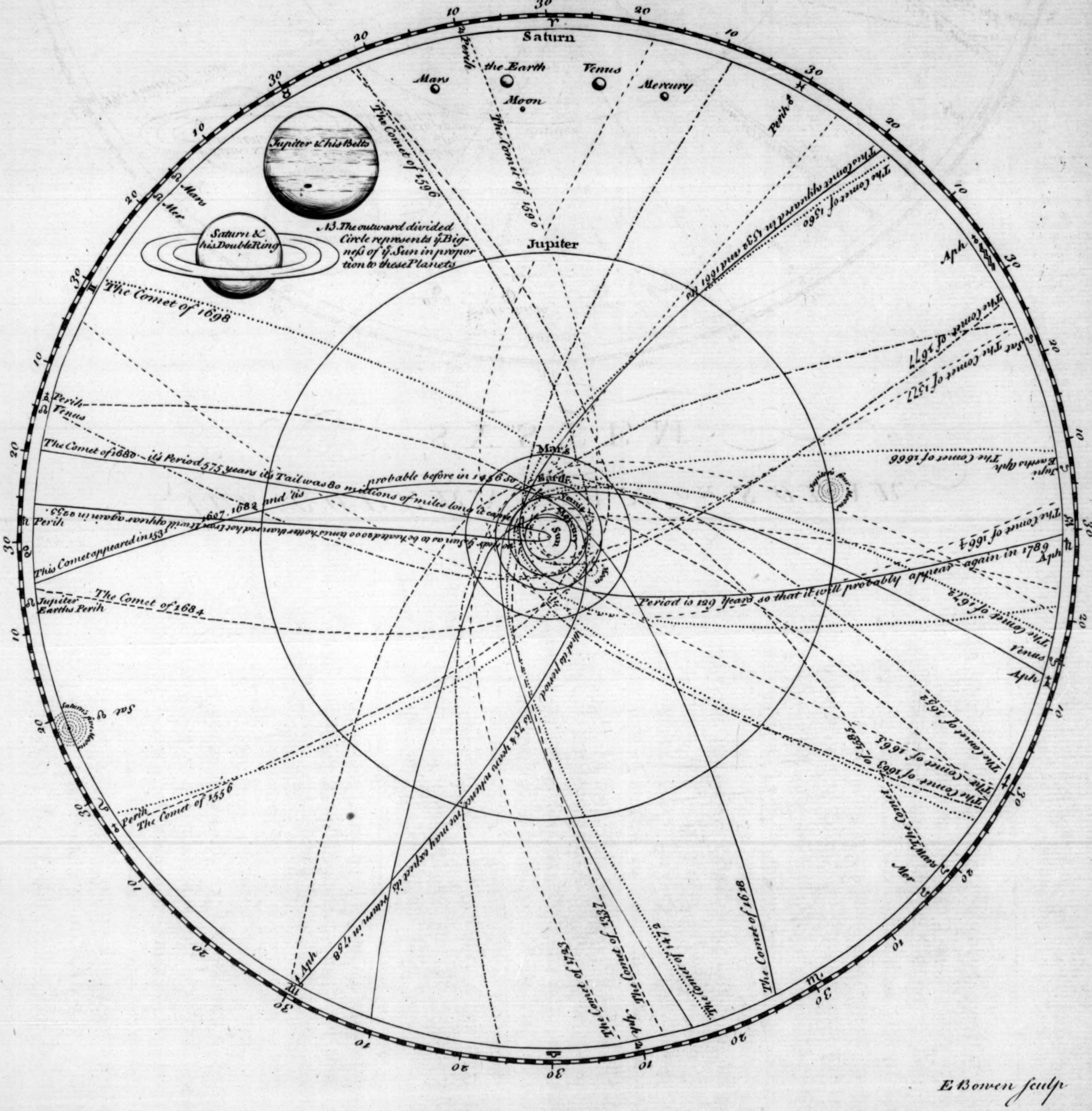
Sun, which will conſtitute all *the Variety of Seaſons*, as will moſt naturally and evidently be ſhewn in the Orrery, as follows.

WE will firſt give the Earth Motion in the firſt Point of *Libra*; the Sun will then appear to enter *Aries*, and this will be the *Vernal Equinox*; for now, *the Sun being in the Equinoctial*, all Parts of the Earth will be equally enlighten'd from Pole to Pole, and all the Parallels of Latitude divided into two equal Parts by the *Circle of Illumination.* Hence the Days and Nights will be equal, and the Sun's Heat is now at a Mean between the greateſt and the leaſt: All which Particulars conſtitute that agreeable Seaſon we call the SPRING; the Middle of which is ſhewn by the Index to be the 11*th* of *March.*

As the Earth paſſes on from Weſt to Eaſt, through *Libra*, *Scorpio*, and *Sagittarius*, to the Beginning of *Capricorn*, the Sun will appear from the Earth to move through the oppoſite Signs of the Ecliptic, viz. *Aries*, *Taurus*, *Gemini*, to the Beginning of *Cancer*; during which Time, by the inclined Poſition of the Earth's Axis, the *Northern* Parts will be gradually turn'd towards the Sun, and the *Southern* Parts from it; whence the Sun's Rays will fall more and more directly on the former, and paſs through a ſtill leſs Quantity of the *Atmoſphere*; but in the *Southern* Parts, the reverſe. Alſo in the *Northern* Parts the Arches of the Parallels in the *enlighten'd Hemiſphere* will continually increaſe, and thoſe in the *dark* one decreaſe, ſhewing the conſtant Increaſe of the Days, and Decreaſe of the Nights: All which will be in their greateſt Degree when the Sun is arrived to *Cancer*; and therefore that will be the Middle of that Seaſon we call SUMMER, in *Northern Latitude*; but in *Southern Latitude* every thing will be the reverſe, and their Seaſon *Winter.*

THE *North Frigid Zone* is now wholly enlighten'd, and the Pole turn'd towards the Sun as far as poſſible; but now as the Earth moves on, the *North* Pole returns, the Diurnal Arches begin gradually to decreaſe, and the Nocturnal to increaſe; and of

THE COPERNICAN OR SOLAR SYSTEM



N.B. The outward divided Circle represents ye Bigness of ye Sun in proportion to these Planets

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Fig. XI.III.

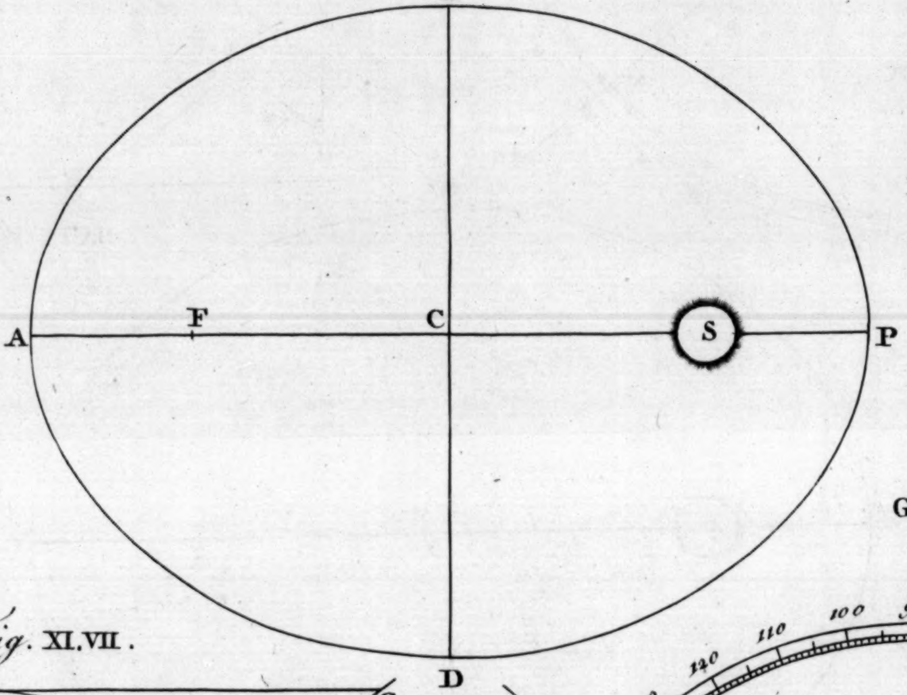
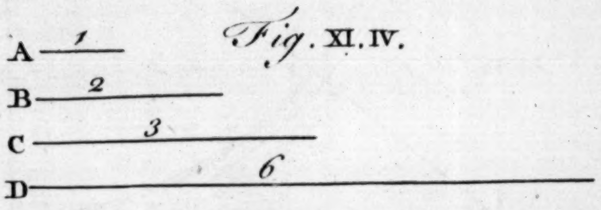


Fig. XI.IV.



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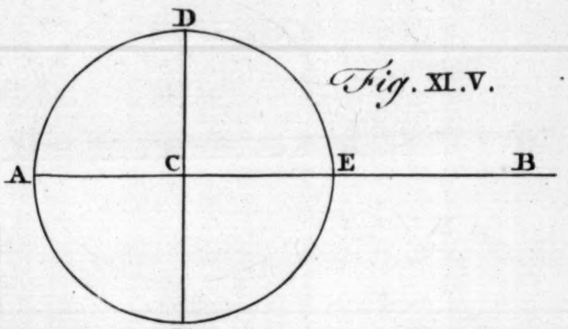


Fig. XI.VII.

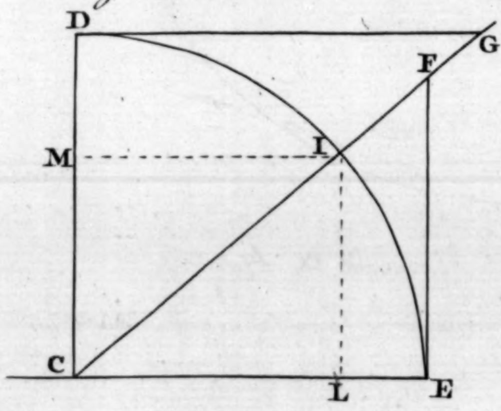
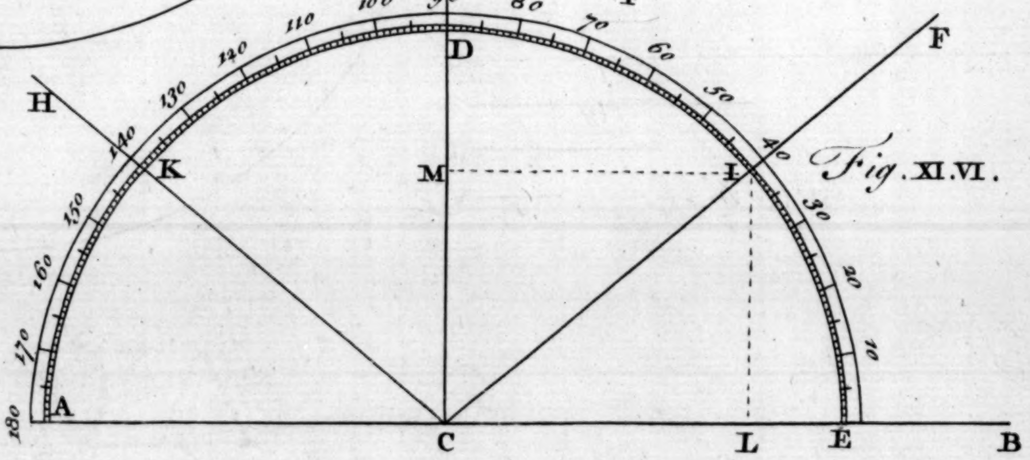


Fig. XI.VI.



conſequence the Sun's Rays fall more and more obliquely, and his Heat proportionally diminiſhes till the Earth comes to *Aries*, when the Sun will appear in *Libra*; and thus produce an Equality of Light and Heat, of Day and Night, to all Parts of the World. This will be the Middle of the Seaſon call'd AUTUMN, and that Day, the *Autumnal Equinox*.

BUT as the Earth goes on through *Aries*, *Taurus*, and *Gemini*, you will ſee the Sun paſs through the oppoſite Signs of *Libra*, *Scorpio*, *Sagittarius*. The *North* Pole is now in the dark Hemiſphere, and the *Frigid Zone* is now more and more obſcured therein: All *Northern Latitudes* continue gradually turning from the Sun; and his Rays fall more and more obliquely on them, and paſs through a larger Body of the Atmoſphere: The *nocturnal Arches* continue to increaſe, and the *diurnal* to decreaſe: All which contribute to make the diſmal dreary Seaſon we call WINTER; the Midſt whereof is ſhewn by the Sun's entering the firſt Scruple of *Capricorn* on the 10*th* of *December*, as by the Index may be ſeen.

LASTLY: As the Earth journeys on from thence through *Cancer*, *Leo*, and *Virgo*, the Sun appears to paſs through *Capricorn*, *Aquarius*, and *Piſces*; and all Things change their Face. The *Northern* Climes begin to return, and receive more directly the enlivening Beams of the Sun, whoſe Meridian Height does now each Day increaſe; the Days now lengthen, and the tedious Nights contract their reſpective Arches; and every thing conſpires to advance the delightful Seaſon of the SPRING, the Midſt whereof is ſhewn by the Earth's returning again to that Point, where firſt we gave it Motion.

ALL theſe Appearances of the Seaſons, *&c.* are ſhewn as well for the *Southern Latitudes*, where at the ſame Time they happen in Order juſt the reverſe to what we have now obſerved for the *Northern*. Thus, when it is *Summer* with us, it is *Winter* with them, and they have their Days ſhorteſt when ours are longeſt; and *vice verſa*. All which is moſt diſtinctly ſeen in the Orrery.

AT the ſame Time the Earth is going round the Sun, the Moon is ſeen conſtantly circulating round the Earth once in 29 Days and a half; which Days are number'd on a ſilver'd Circle, and ſhewn by an Index moving over them. Thus each Day of the Moon's Age, and the *Phaſis* proper thereto, are ſhewn for any required Time; and alſo why we ſee always *one and the ſame Face of the Moon*, *viz.* on account of her *turning about her own Axis in the ſame Time ſhe takes to revolve about the Earth.*

AGAIN: By placing a Lamp in the Orrery, and making the Room dark, we ſee very naturally how the *Sun is eclipſed* by the New Moon, and the Shadow paſſing over the Diſk of the Earth; and alſo how the Moon, at Full, is eclipſed by paſſing through the Shadow of the Earth. Here alſo we ſee the Manner how *Mercury* and *Venus* tranſit the Sun's Face in form of a *dark round Spot*; and alſo why they can never appear at a great Diſtance from the Sun; and various other *Phænomena*, of the like Nature.

THE COMETARIUM is a very curious Machine, which exhibits an Idea of the Motion or Revolution of a Comet about the Sun; and as this Sort of Motion is not perform'd in *circular*, but very *elliptic Orbits*, ſo in this Inſtrument, a peculiar Contrivance by *elliptical Wheels* is neceſſary to effect it; which as a great Curioſity will be ſhewn, together with all Parts of the Machine, in my new Conſtruction thereof. The Comet here repreſented is that which appear'd in the Year 1682, whoſe Period is 75 Years and a half, and therefore will again appear in 1758. By this Piece of Machinery is ſhewn the *unequal Motion* of a Comet in every Part of its Orbit; the great Velocity with which it moves in the *Perihelion* Part of its Orbit, and how from thence it moves with a retarded Velocity till it arrives at the *Aphelion* Point, where its Motion is ſloweſt of all; and from thence it is ſeen continually accelerating its Motion towards the *Perihelium*, in ſuch manner as the Laws of Attraction require. The Comet is repreſented by a ſmall Braſs Ball, carried by a *Radius Vector*, or Wire, in an *elliptic Groove*, about the Sun in one of its *Foci*; and the Years of its Period are ſhewn by an Index moving with an equable Motion over a graduated ſilver'd Circle: The Whole being a juſt Repreſentation of the preſent Theory of thoſe prodigious and wonderful *Phænomena* of the Planetary Syſtem.

LECTURE XII.

The Uſe of the GLOBES.

IN this Lecture I ſhall explain the *Nature and Uſe of both the Globes*, by giving you a ſuccinct Account of the Nature and Deſign of each, and a Solution of the *principal Problems* that are uſually perform'd thereby.

EACH Globe is ſuſpended in a General Meridian, and moveable (within an Horizon) about its Axis, in the ſame manner as the *Armillary Sphere* of the Orrery; and the Circles of that Sphere, already deſcribed, are laid on the correſponding Parts of the Surface of each Globe; and are therefore ſuppoſed to be known.

THE Surface of the CELESTIAL GLOBE is a Repreſentation of the concave Surface of the *Starry Firmament*, there being depicted all the Stars of the firſt and ſecond Magnitude, and the moſt noted of all the reſt that are viſible. So that by this Globe we may ſhew the *Face of the Heavens* for any required Time, by Day or Night, throughout the Year, in general; or in regard to any particular Body, as the *Sun*, *Moon*, *Planet*, or *Fix'd Star*.

THE Stars are all diſpoſed into Conſtellations, under the Forms of various Animals, whoſe Names and Figures are printed on the Paper which covers the Globe; which were invented by the ancient Aſtronomers and Poets, and are ſtill retain'd for the ſake of Diſtinction and better Arrangement of thoſe Luminaries, which would be otherwiſe too confuſed and promiſcuous for eaſy Conception, and a regular Method of treating on them.

IN order to underſtand the following Problems, it will be neceſſary to premiſe the following Definitions in relation thereto, *viz.*

I. THE DECLINATION of the Sun and Stars is their Diſtance from the *Equinoctial* in Degrees of the General Meridian, towards either Pole, *North* or *South.*

II. RIGHT ASCENSION is that Degree of the Equinoctial reckon'd from the Beginning of *Aries*, which comes to the Meridian with the Sun or Star.

III. OBLIQUE ASCENSION is that Degree of the Equinoctial which comes to the Horizon when the Sun or Star is riſing: And *Oblique Deſcenſion* is that Point which comes to the Horizon on the Weſt Part, when the Sun or Star is deſcending or ſetting in an oblique Sphere.

IV. ASCENSIONAL DIFFERENCE is the Difference between the *Right* and *Oblique Aſcenſion.*

V. THE LONGITUDE of the Sun or Star is an Arch of the Ecliptic, between the firſt Point of *Aries*, and that Point of the Ecliptic to which the Luminary is referr'd by the Meridian paſſing through it; and is therefore reckon'd in Signs and Degrees of the Ecliptic.

VI. THE LATITUDE of a Star is its Diſtance from the Ecliptic towards the North or South Pole.

VII. AMPLITUDE is the Diſtance at which the Sun or Star riſes or ſets, from the Eaſt or Weſt Point of the Horizon, towards the North or South.

VIII. AZIMUTH is the Diſtance between the North Point of the Horizon, and the Point where the Vertical Circle, paſſing through the Body of the Sun or Star, cuts the Horizon.

IX. THE ALTITUDE of the Sun or Star is its Height above the

Horizon, meaſured in the Degrees of the *Quadrant of Altitude*, or moveable *Azimuth Circle*.

X. A Star is ſaid to riſe or ſet *Coſmically*, when it riſes or ſets when the Sun riſes.

XI. A Star riſes *Acronically*, if it riſes when the Sun ſets.

XII. A Star riſes *Heliacally*, when it emerges out of the Sun-beams, and is ſeen in the Morning before Sun-riſing: And it ſets *Heliacally*, when it is ſo near the Sun that it cannot be ſeen.

XIII. A *Right Sphere* is that whoſe Poles are in the Horizon and the Equinoctial, and all its Parallels cut the Horizon at Right Angles.

XIV. A *Parallel Sphere* is that whoſe Poles co-incide with the Poles of the Horizon, or *Zenith* and *Nadir*; and the Equinoctial with the Horizon; and all the Parallels, parallel thereto.

XV. AN *Oblique Sphere* is that, one of whoſe Poles is above the Horizon, and the other below it; and the Equinoctial and its Parallels obliquely cutting the ſame.

THE *Problems* on the *Celeſtial Globe* are the following.

PROB. I. *To rectify the Globe:*

ELEVATE the Pole to the Latitude of the Place, and every thing as directed under PROB. II. of the *Terreſtrial Globe*, which ſee.

PROB. II. *To find the* SUN'S PLACE *in the Ecliptic:*

FIND the Day of the Month in the Calendar on the Horizon, and right againſt it is the Degree of the Ecliptic which the Sun is in for that Day.

PROB. III. *To find the Sun's* DECLINATION:

RECTIFY the Globe, bring the Sun's Place in the Ecliptic to the Meridian, and that Degree which it cuts in the Meridian is the Declination required.

PROB. IV. *To find the Sun's* RIGHT ASCENSION:

BRING the Sun's Place to the Meridian, and the Degree in which the Meridian cuts the Equinoctial is the Right Aſcenſion required.

PROB. V. *To find the Sun's* AMPLITUDE:

BRING the Sun's Place to the Horizon, and the Arch of the Horizon between it and the Eaſt or Weſt Point is the Amplitude, North or South.

PROB. VI. *To find the Sun's* ALTITUDE *for any given Day and Hour:*

BRING the Sun's Place to the Meridian; ſet the Hour-Index to the upper XII; then turn the Globe till the Index points to the given Hour, where let it ſtand; then ſcrewing the Quadrant of Altitude in the *Zenith*, lay it over the Sun's Place, and the Arch contained between it and the Horizon will give the Degrees of Altitude required.

PROB. VII. *To find the Sun's* AZIMUTH *for any Hour of the Day:*

EVERY thing being done as in the laſt Problem, the Arch of the Horizon contain'd between the North Point and that where the Quadrant of Altitude cuts it, is the *Azimuth* Eaſt or Weſt, as required.

PROB. VIII. *To find the Time when the Sun riſes or ſets:*

FIND the Sun's Place for the given Day; bring it to the Meridian, and ſet the Hour-Hand to XII; then turn the Globe till the Sun's Place touches the Eaſt Part of the Horizon, the Index will ſhew the Hour of its Riſing: After that, turn the Globe to the Weſt Part of the Horizon, and the Index will ſhew the Time of its Setting for the given Day.

PROB. IX. *To find the Length of any given Day or Night:*

THIS is eaſily known by taking the Number of Hours between the Riſing and Setting of the Sun for the Length of the Day; and the Reſidue, to 24, for the Length of the Night.

PROB. X. *To find the Hour of the Day, having the Sun's Altitude given:*

BRING the Sun's Place to the Meridian, and ſet the Hour-Hand to XII; then turn the Globe in ſuch manner, that the Sun's Place may move along by the Quadrant of Altitude, (fix'd in the *Zenith*) till it touches the Degree of the given Altitude; where ſtop it, and the Index will ſhew on the *Horary Circle* the Hour required.

PROB. XI. *To find the Place of the* MOON *or any* PLANET, *for any given Day:*

TAKE *Parker*'s or *Weaver*'s *Ephemeris*, and againſt the given Day of the Month you will find the Degree and Minute of the Sign which the Moon or Planet poſſeſſes at *Noon*, under the Title of *Geocentric Motions*. The Degree thus found, being mark'd in the Ecliptic on the Globe by a ſmall Patch, or otherwiſe; you may then proceed to find the *Declination*, *Right Aſcenſion*, *Latitude*, *Longitude*, *Altitude*, *Azimuth*, *Riſing*, *Southing*, *Setting*, *&c.* in the ſame manner as has been ſhewn for the Sun.

PROB. XII. *To explain the Phænomena of the* HARVEST-MOON:

IN order to this we need only conſider, that when the Sun is in the Beginning of *Aries*, the Full Moon on that Day muſt be in the Beginning of *Libra:* And ſince when the Sun ſets, or Moon riſes, on that Day, thoſe Equinoctial Points will be in the Horizon, and the Ecliptic will then be leaſt of all inclined thereto, the Part or Arch which the Moon deſcribes in one Day, *viz.* 13 Degrees, will take up about an Hour and a Quarter aſcending above the Horizon; and therefore ſo long will be the Time after Sun-ſet, the next Night, before the Moon will riſe. But at the oppoſite Time of the Year, when the Sun is in the *Autumnal*, and Full Moon in the *Vernal Equinox*, the Ecliptic will, when the Sun is ſetting, have the greateſt Inclination to the Horizon; and therefore 13 Degrees will in this Caſe ſoon aſcend, *viz.* in about a

Quarter of an Hour; and ſo long after Sun-ſet will the Moon riſe the next Day after Full: Whence, at this Time of the Year, there is much more Moon-Light than in the Spring; and hence this Autumnal Full Moon came to be call'd the *Harveſt Moon*, the *Hunter's* or *Shepherd's Moon*: All which will clearly be ſhewn on the Globe.

PROB. XIII. *To repreſent the Face of the Starry Firmament for any given Hour of the Night:*

RECTIFY the Globe; and turn it about, till the Index points to the given Hour; then will all the upper Hemiſphere of the Globe repreſent the viſible Half of the Heavens, and all the Stars on the Globe will be in ſuch Situations as exactly correſpond to thoſe in the Heavens; which may therefore be eaſily found, as will be ſhewn.

PROB. XIV. *To find the Hour when any known Star will riſe, or come upon the Meridian:*

RECTIFY the Globe, and ſet the Index to XII; then turn the Globe till the Star comes to the Horizon or Meridian, and the Index will ſhew the Hour required.

PROB. XV. *To find at what Time of the Year any given Star will be on the Meridian at* XII *at Night:*

BRING the Star to the Meridian, and obſerve what Degree of the Ecliptic is on the North Meridian under the Horizon; then find in the Calendar on the Horizon the Day of the Year againſt that Degree, and it will be the Day required.

THESE are the chief *Problems* on the *Celeſtial Globe:* We now proceed to thoſe on the *Terreſtrial*; but ſhall firſt premiſe the following Definitions relating thereto.

I. THE LATITUDE of any Place is its Diſtance from the Equator towards either Pole; and is reckon'd in Degrees of the General Meridian, beginning at the Equator.

II. LONGITUDE is the Diſtance between the Meridian of any Place, and the firſt or ſtanding Meridian, reckon'd in the Degrees of the Equator towards the Eaſt or Weſt.

III. A CLIMATE is a Space of the Earth's Surface, parallel to the Equator, where the Length of the Day is *half an Hour* longer in the Parallel which bounds it on the North, than in that which terminates it on the South.

IV. A ZONE is alſo a Diviſion of the Earth's Surface parallel to the Equator, in regard of the different Degrees of *Heat and Cold*, which we have deſcribed in the preceding Lecture.

V. THE ANTOECI are thoſe Inhabitants of the Earth, who live under the ſame Meridian, but on oppoſite Parallels, and are therefore equally diſtant from the Equator. Their Noon and Midnight are at the ſame Time; the Days of one are equal to the Nights of the other; and their Seaſons of the Year are contrary.

VI. THE PERIOECI are thoſe People who live under the ſame Parallel, but oppoſite Meridians. The ſame Pole is elevated and depreſs'd to both; are equally diſtant from the Equator, and on the ſame Side; when Noon to one, it is Midnight to the other; the Length of Days to one is the Complement of Night to the other, and the contrary; and the Seaſons of the Year are the ſame to both, at the ſame Time.

VII. THE ANTIPODES are thoſe who live *Feet to Feet*, or under *oppoſite Parallels and Meridians*. They are equally diſtant from the Equator on different Sides; have the contrary Poles equally elevated; the Noon of one is Midnight to the other; the longeſt Day or Night to one is ſhorteſt to the other; and the Seaſons of the Year are contrary, *&c.*

VIII. ALSO the Inhabitants of the Torrid Zone are call'd AMPHISCII, becauſe their *Shadows fall on both Sides* of them.

IX. THOSE of the Frigid Zone are called PERISCII, becauſe their *Shadows fall all around* them.

X. AND the Inhabitants of the Temperate Zones are call'd HETEROSCII, becauſe they caſt *their Shadows only one way.*

XI. A CONTINENT is the largeſt Diviſion or Space of Land, comprehending divers Countries and Kingdoms, not ſeparated by Water.

XII. AN ISLAND is any ſmall Tract of Land ſurrounded by Water.

XIII. A PENINSULA is a Part of Land encompaſs'd with Water all around, except on one Part, which is call'd

XIV. AN ISTHMUS, being that narrow Neck of Land which joins it to the Continent.

XV. A PROMONTORY is a mountainous Part of Land ſtanding far out in the Sea; whoſe Fore-part is call'd a *Cape*, or *Head-Land.*

XVI. THE OCEAN is the largeſt Collection of Waters, which lies between, and environs the Continents.

XVII. THE SEA is a ſmaller Part of the aqueous Surface of the Earth, interceding the Iſlands, Promontories, *&c.*

XVIII. A GULF is a Part of the Sea every where environ'd with Land, except on one ſmall Part call'd

XIX. A STRAIT, which is that narrow Paſſage joining it to the adjacent Sea.

XX. A LAKE is any large Quantity of ſtagnant Water entirely ſurrounded by Land.

THE other Parts of Land or Water need no Explanation.

I SHALL now proceed to the Solution of the moſt uſeful *Problems* on the *Terreſtrial Globe*, firſt premiſing that *the Latitude of a Place is equal to the Elevation of the Pole at that Place*; for if the Arch of the Meridian between the Place and the Pole be added to the Latitude of the Place, it makes 90 Degrees; alſo if it be added to the Pole's Elevation, or Arch between the Pole and Horizon, the Sum is 90 Degrees: Whence the Propoſition is evident.

PROB. I. *To find the Latitude of any Place:*

BRING the given Place to the Brazen Meridian, and obſerve what Degree it is under, for that is the Latitude required.

PROB. II. *To rectify the Globe for any given Place:*

RAISE the Pole ſo high above the Horizon, as is equal to the Latitude of the Place; ſcrew the Quadrant of Altitude in the *Zenith*; find the Sun's Place, and bring it to the Meridian; ſet the Hour-Hand to the upper XII; and place the Globe North and South by a Needle; then is it a juſt Repreſentation of the Globe of the Earth, in regard of that Place, for the given Day at Noon.

PROB. III. *To find the Longitude of a given Place:*

BRING the Place to the Brazen Meridian, and obſerve the Degree of the Equator under the ſame, for that expreſſes the Longitude required.

PROB. IV. *To find any Place by the Latitude and Longitude given:*

BRING the given Degree of Longitude to the Meridian, and under the given Degree of Latitude you will ſee the Place required.

PROB. V. *To find all thoſe Places which have the ſame Latitude and Longitude with thoſe of any given Place:*

BRING the given Place to the Meridian, then all thoſe Places which lie under the Meridian have the ſame Longitude: Again, turn the Globe round on its Axis; then all thoſe Places, which paſs under the ſame Degree of the Meridian with any given Place, have the ſame Latitude with it.

PROB. VI. *To find all thoſe Places where it is Noon at any given Hour of the Day, in any Place:*

BRING the given Place to the Meridian; ſet the Index to the given Hour; then turn the Globe, till the ſaid Index points to the upper XII; and obſerve what Places lie under the Braſs Meridian, for to them it is Noon at that Time.

PROB. VII. *When it is Noon at any one Place, to find what Hour it is at any other given Place:*

BRING the firſt given Place to the Meridian, and ſet the Index to the upper XII; then turn the Globe till the other given Place comes to the Meridian, and the Index will point to the Hour required.

PROB. VIII. *For any given Hour of the Day in the Place where you are, to find the Hour of the Day in any other Place:*

BRING the Place where you are to the Meridian, ſet the Index to the given Hour; then turn the Globe about, and when the other Place comes to the Meridian, the Index will ſhew the Hour of the Day there, as required.

PROB. IX. *To find the Diſtance between any two Places on the Globe in* Engliſh *Miles:*

BRING one Place to the Meridian, over which fix the Quadrant of Altitude; and then laying it over the other Place, count the Number of Degrees thereon contain'd between them; which Number multiply by 69 and a half, (the Number of Miles in one Degree) and the Product is the Number of *Engliſh* Miles required.

PROB. X. *To find how any one Place bears from another:*

BRING one Place to the Braſs Meridian, and lay the Quadrant of Altitude over the other; and it will ſhew on the Horizon the Point of the Compaſs on which the latter bears from the former.

PROB. XI. *To find thoſe Places to which the Sun is vertical in the Torrid Zone, for any given Day:*

FIND the Sun's Place in the Ecliptic for the given Time, and bring it to the Meridian, and obſerve what Degree thereof it cuts; then turn the Globe about, and all thoſe Places which paſs under that Degree of the Meridian are thoſe required.

PROB. XII. *To find what Day of the Year the Sun will be vertical to any given Place in the Torrid Zone:*

BRING the given Place to the Meridian, and mark the Degree exactly over it; then turn the Globe round, and obſerve the two Points of the Ecliptic which paſs under that Degree of the Meridian: Laſtly, ſee on the Wooden Horizon, on what Days of the Year the Sun is in thoſe Points of the Ecliptic; for thoſe are the Days required.

PROB. XIII. *To find thoſe Places in the North Frigid Zone, where the Sun begins to ſhine conſtantly without ſetting, on any given Day between the* 10th *of* March *and the* 10th *of* June:

FIND the Sun's Place in the Ecliptic for the given Day; bring it to the General Meridian, and obſerve the Degrees of Declination; then all thoſe Places which are the ſame Number of Degrees diſtant from the Pole, are the Places required to be found.

PROB. XIV. *To find on what Day the Sun begins to ſhine conſtantly without ſetting, on any given Place in the North Frigid Zone, and how long:*

RECTIFY the Globe to the Latitude of the Place; and, turning it about, obſerve what Point of the Ecliptic between *Aries* and *Cancer*, and alſo between *Cancer* and *Libra*, co-incides with the North Point of the Horizon; then find, by the Calendar on the Horizon, what Days the Sun will enter thoſe Degrees of the Ecliptic, and they will ſatisfy the Problem.

PROB. XV. *To find the Place over which the Sun is vertical, on any given Day and Hour:*

FIND the Sun's Place, and bring it to the Meridian, and mark the Degree of Declination for the given Hour; then find thoſe Places which have the Sun in the Meridian at that Moment; and among them, that which paſſes under the Degree of Declination is the Place deſired.

PROB. XVI. *To find, for any given Day and Hour, thoſe Places wherein the Sun is then riſing, or ſetting, or on the Meridian: Alſo thoſe Places which are enlighten'd, and thoſe which are not:*

FIND the Place to which the Sun is vertical at the given Time, and bring the ſame to the Meridian, and elevate the Pole to the Latitude of the Place; then all thoſe Places which are in the Weſtern Semicircle of the Horizon have the Sun *riſing*, and thoſe in the Eaſtern Semicircle ſee it *ſetting*; and to thoſe under the Meridian, it is *Noon*. Laſtly, all Places above the Horizon are enlighten'd, and all below it are in Darkneſs or Night.

PROB. XVII. *The Day and Hour of a Solar or Lunar Eclipſe being given, to find all thoſe Places in which the ſame will be viſible:*

FIND the Place to which the Sun is vertical at the given Inſtant, and elevate the Globe to the Latitude of the Place; then in moſt of thoſe Places above the Horizon will the Sun be viſible during his Eclipſe; and all thoſe Places below the Horizon will ſee the Moon paſs through the Shadow of the Earth in her Eclipſe.

PROB. XVIII. *The Length of a Degree being given, to find the Number of Miles in a great Circle of the Earth, and thence the Diameter of the Earth:*

ADMIT that one Degree contains $69\frac{1}{2}$ *Engliſh* Statute Miles; then multiply 360 (the Number of Degrees in a Great Circle) by $69\frac{1}{2}$, and the Product will be 25020, the Miles which meaſure the Circumference of the Earth. If this Number be divided by 3.1416, the Quotient will be $7963\frac{86}{100}$ Miles, for the Diameter of the Earth.

PROB. XIX. *The Diameter of the Earth being known, to find the Surface in Square Miles, and its Solidity in Cubic Miles:*

ADMIT the Diameter be 7964 Miles; then multiply the Square of the Diameter by 3.1416, and the Product will be 199250205 very near, which are the Square Miles in the Surface of the Earth. Again, multiply the Cube of the Diameter by 0.5236, and the Product 264466789170 will be the Number of Cubic Miles in the whole Globe of the Earth.

PROB. XX. *To expreſs the Velocity of the diurnal Motion of the Earth:*

SINCE a Place in the Equator deſcribes a Circle of 25020 Miles in 24 Hours, 'tis evident the Velocity with which it moves is at the rate of $1042\frac{1}{2}$ in one Hour, or $17\frac{3}{10}$ Miles *per* Minute. The Velocity in any Parallel of Latitude decreaſes in the Proportion of the *Co-Sine of the Latitude to the Radius.* Thus, for the Latitude of *London,* 51 deg. 30 min. ſay,

As Radius -	10.000000
To the Co-Sine of Lat. 51 deg. 30 min. - - - - -	9.794149
So is the Velocity in the Equator, $17\frac{3}{10}$ m. - - - - -	2.232046
To the Velocity of the City of *London,* $10\frac{8}{10}$ m. - -	2.032195

That is, the City of *London* moves about the Axis of the Earth at the Rate of $10\frac{8}{10}$ Miles every Minute of Time. But this is far ſhort of the Velocity of the annual Motion about the Sun; for that is at the Rate of 56000 Miles *per* Hour, or about 940 Miles each Minute, ſuppoſing the Diameter of the annual Orbit to be 81 Millions of Miles.

THERE is a geometrical Method of deſcribing the Superficies of the Celeſtial and Terreſtrial Globe on a Plane; and this is call'd the *Projection of the Sphere in Plano:* Thus, one Half of the Globe is projected on one Side of the Plane, and the other Half on the other; and if the Plane be that of the Ecliptic or Equinoctial, as in the Caſe of the Celeſtial Globe, theſe Projections are then call'd the *Celeſtial Hemiſpheres.* But with regard to the Terreſtrial Globe, they are generally made on the Plane of the *General Meridian or Horizon,* and then they are commonly call'd *Maps of the World:* And the ſeveral Circles, and Parts of the

Surface of one Hemiſphere, are ſo delineated on the ſaid Plane, as they would appear thereon to an Eye placed in the Pole, or middle Point, of the other Hemiſphere. Hence it will come to paſs, that the Stars and Conſtellations of the Hemiſpheres, and the Parts of Land and Water in the Maps, are not repreſented in their natural and juſt Diſtances, and in their due Magnitudes and Forms, as on the Globes themſelves: Yet moſt of the Problems of either Globe are performable on theſe artificial Projections, by thoſe who underſtand their Nature and Uſe. But theſe Things will be beſt underſtood from a View of thoſe Prints, and a Specimen of the Praxis of their Uſe.

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AN
APPENDIX,
CONTAINING AN
EXPLICATION
OF SUCH
CHARACTERS, WORDS, and PHRASES,
As are not explain'd in the foregoing LECTURES, and other TREATISES of this Kind.

FOR the Sake of ſuch Gentlemen and Ladies as are not mathematically learned, it will be neceſſary to explain ſome *Characters*, *Terms*, and *Words*, that occur in the preceding LECTURES, and other Books on the like Subject, that nothing may be wanting to facilitate and expedite their Progreſs in theſe moſt important and ſublime Studies.

IN all Caſes where the Uſe of Numbers is required, it is now cuſtomary, inſtead of the Words *Addition*, *Subſtraction*, *Multiplication*, *Diviſion*, &c. to uſe Characters, for the ſake of Brevity, to expreſs the ſame Things. Thus, for *Addition* we uſe the Sign +; as 5 + 3, is to be read 5 more 3, or 3 added to 5.

So for *Subſtraction* we uſe the Sign —; as 5 — 3, is 5 leſs 3, or 3 ſubſtracted from 5.

FOR *Multiplication* we uſe the Sign x; thus 5 x 3, is 5 multiplied by 3.

AND for *Diviſion* is uſed the Sign ÷; thus 15 ÷ 3, is 15 divided by 3; but this is not ſo frequent.

AGAIN, when we would expreſs *Equality*, we uſe the Sign =; 5 + 3 = 8, that is, 5 more 3 is equal to 8; and 5 x 3 = 15, is 5 multiplied by 3 is equal to 15.

In ſtating *Proportions* we uſe the Sign : for *is to*, and :: for *ſo is*. Thus, inſtead of ſaying, As A is to B, ſo is C to D, we expreſs it thus, A : B :: C : D.

The Square of any Number is the Product of that Number multiplied by itſelf; thus the Square of 3 is $3 \times 3 = 9$; and the Cube of a Number is the Product of that Number multiplied by itſelf twice; thus the Cube of 3 is $3 \times 3 \times 3 = 27$. Hence the Number 3 is ſaid to be the *Square Root* of 9, and the *Cube Root* of 27; and in Characters the *Square Root* is thus expreſs'd $\sqrt[2]{\;}$, and the *Cube Root* thus $\sqrt[3]{\;}$; thus $\sqrt[2]{9} = 3$, and $\sqrt[3]{27} = 3$; and ſo of other Numbers or Quantities.

When any Quantity cannot be expreſſed in whole Numbers without Fractional Parts, 'tis common now to expreſs thoſe broken Parts in *Decimal Numbers*, which are diſtinguiſh'd from the *Whole Number* by a Point or *Comma*: Thus 3,5 is 3 and 5 Tenths of another, or $3{,}5 = 3\frac{5}{10} = 3\frac{1}{2}$; ſo 3,1416 is $3\frac{1416}{10000}$; that is, if the Diameter of a Globe be one Foot, the Circle which divides it into two equal Parts will be 3,1416, or $3\frac{1416}{10000}$ Feet; that is, it will be 3 Feet, and 1416 of 10000 Parts of another Foot: And ſo of other Decimal Numbers.

Proportion is the Compariſon of Things in reſpect of Magnitude: Thus we ſay four Lines, A, B, C, D, are *proportional*, when A is to B as C is to D in regard of their Length. And in this Caſe, the Rectangle or Product of the two Extremes is equal to the Rectangle of the two Means, or Middle Lines, *viz.* $A \times D = B \times C$. If here, while the two firſt Quantities A and B do increaſe or decreaſe, the other two C and D do alſo proportionably increaſe or decreaſe, the Proportion is ſaid to be *direct*. *Note*, When Quantities multiplied together are expreſſed by ſingle Letters, we leave out the Mark ×, and inſtead of $A \times D$, write only AD. But if while two Quantities A, B, do increaſe or decreaſe, other two Quantities C, D, ſhould at the ſame Time proportionably decreaſe or increaſe; then the Proportion between thoſe Quantities is ſaid to be *inverſe* or *reciprocal.* Thus, becauſe as the Squares of the Diſtances from the Sun increaſe, the Effects of its Light and Heat decreaſe, the latter are ſaid to be *reciprocally proportional* to the former.

Fig. XLIV.

When any two Quantities are proportional to other two Quantities ſingly, the Proportion is ſaid to be *ſimple*: Thus the Circumferences of two unequal Circles are in the *ſimple Proportion of their Diameters.*

But if two Quantities are in Proportion to each other as the *Squares* of two other Quantities, the Proportion is ſaid to be *duplicate*: Thus becauſe the *Lengths of Pendulums* are to each other as the *Squares of the Times of their Vibrations*, therefore the *former* are ſaid to be in the *duplicate Proportion* of the *latter*.

In the ſame manner, if two Quantities are proportional to the *Cubes* of two other Quantities, the *former* are ſaid to be in the *triplicate Proportion* of the *latter*. Thus Spheres or Globes are in the *triplicate Proportion* of their Diameters, becauſe their Magnitudes are as the Cubes of the Diameters.

When the Squares of any two Quantities are proportional to the *Cubes* of two others, the Proportion is ſaid to be *ſeſquiplicate:* Thus, becauſe the *Squares of the Times*, in which any two Planets revolve about the Sun, are proportional to the *Cubes of their Diſtances* reſpectively, the *former* are ſaid to be in a *ſeſquiplicate Proportion* of the *latter*.

If two Quantities have the ſame Proportion as the *Square Roots* of two other Quantities, then the Proportion is ſaid to be *ſubduplicate:* Thus the Times of Vibration are ſaid to be in the *ſubduplicate Proportion of the Lengths of Pendulums*, becauſe they are as the *Square Roots of thoſe Lengths.*

And *ſubtriplicate Proportion* is that of the *Cube Roots:* Thus the *Diameters of Spheres* are in the *ſubtriplicate Proportion* of the Spheres themſelves. For Example: Let two Spheres or Globes be to each other as 8 and 27; now the Cube Roots of theſe Numbers are 2 and 3, which therefore will repreſent the Diameters of the Spheres; and thus we ſay, 2 is to 3 in the *ſubtriplicate Proportion* of 8 to 27.

I shall here exhibit the ſeveral Kinds of Proportion in one View, thus:

Simple Proportion	$A:B::C:D$ — —	$2:3::6:9$
Duplicate — —	$A:B::CC:DD$ —	$4:9::16:36$
Triplicate — —	$A:B::CCC:DDD$ —	$1:8::8:64$
Seſquiplicate —	$AA:BB::CCC:DDD$, *or*	$A:B::C\sqrt{C}:D\sqrt{D}$
Subduplicate —	$A:B::\sqrt[2]{C}:\sqrt[2]{D}$ —	$2:3::4:6$
Subtriplicate — —	$A:B::\sqrt[3]{C}:\sqrt[3]{D}$ — —	$1:2::2:4$

I take it for granted that the Reader knows, that if on any Point C, taken in the Right Line AB, a Circle ADEF be deſcribed, the Point C is called the *Center*, and AE the *Diameter* of that Circle: To which I ſhall add, that AC, or CE, is call'd the *Radius* of the Circle, which is the ſame thing as the *Semidiameter*.

Fig. XLV.

If the Circle be divided into four equal Parts, AD = DE = EF = FA, by the two Diameters AE, DF; then each of the Areas ACD, DCE, ECF, FCA, are called *Quadrants*, or Quarters of the circular Space; and the Parts of the Circle AD, DE, EF, FA, are call'd *Quadrantal Arches*, or Quarters of the Circle.

Every Circle, great or ſmall, is ſuppoſed to be divided into 360 equal Parts, call'd *Degrees*; conſequently each Quarter, AD, DE, *&c.* will contain 90 of thoſe Degrees, as is evidently repreſented by the large Half-Circle of *Fig*. XLVI.

If two Lines BC and FC meet in a Point C, the Space FCB included between them is call'd an *Angle*; and the Meaſure of that Angle is the Number

of

of Degrees contain'd in an Arch EI of a Circle deſcribed on the angular Point C, and included between the ſaid two Lines BC and FC. Thus the Angle in the Figure contains 40 Degrees.

IF a Line, as GC, be drawn through the 90th Degree on the Point C, it will make the Angle on one Side GCB equal to the Angle GCA on the other Side, becauſe each is equal to 90 Degrees. Such an Angle is call'd a *Right Angle*; and the Line GC is then ſaid to be *perpendicular* to the Line AB.

THE Angle FCB, which is leſs than a Right Angle or 90 Degrees, is call'd an *Acute Angle*; and the Angle HCB, which is greater than a Right Angle or 90 Degrees, is call'd an *Obtuſe Angle*. Again; the Arch ID is call'd the *Complement* of the Arch EI to a Quadrant ED, or 90 Degrees; and the Arch AK is call'd the *Supplement* of the Arch EK to a Semicircle EDA, or 180 Degrees.

IF from the Point I be let fall the Perpendicular IL to the Line or Radius EC, then is that Line IL call'd the *Sine* of the Angle ICE or FCB. In the ſame manner the Line IM is the Sine of the Complement-Arch ID, or Angle ICD. But inſtead of *Sine-Complement*, we ſay, in ſhort, *Co-Sine*: Thus we ſay that IL is the *Sine*, and IM the *Co-Sine*, of the Angle ICE. The Angle FCB is call'd the *Inclination* of the Line FC to the Line BC; and the Angle FCD is the *Inclination* of the Line FC to the Perpendicular DC: That is, FC is inclined to BC in an Angle of 40 Degrees, and to DC in an Angle of 50 Degrees. Hence IL and IM are call'd the *Sines of Inclination* reſpectively.

HENCE, when we ſay, *The Force of a direct Stroke is to that of an oblique one as Radius is to the Sine of Inclination*, we only mean, that thoſe Quantities are to each other as the Radius IC to the Sine IL, or IM, according as the Inclination is 40 or 50 Degrees. Alſo, when 'tis ſaid, that *the centrifugal Force decreaſes from the Equator towards the Poles, in Proportion of Radius to the Co-Sines of the Latitude*; no more is meant than this, that if the Radius CE repreſent the ſaid Force in the Equator E, and EI be any given Latitude, then will IM, the *Co-Sine* of the Latitude, repreſent the Force in that Latitude: Or, the Force decreaſes with the Length of the Line IM, as the Point I moves on from E to D.

IN ſeveral Books we have Tables of Numbers which expreſs the Length of the Sine of every Degree and Minute of the Quadrant, in ſuch equal Parts as the Radius CE or CI contains 100000. And ſince it is of the greateſt Uſe to know the Proportion of Radius to the Sine of every Degree, I have here ſubjoin'd a Table thereof, and a Specimen of its Uſe.

SINE

	Deg.	Parts.	Deg.	Parts.	Deg.	Parts.	Deg.	Parts.	Deg.	Parts.
SINE of	1	1745	19	32556	37	60181	55	81915	73	95630
	2	3489	20	34202	38	61566	56	82903	74	96126
	3	5233	21	35836	39	62932	57	83867	75	96592
	4	6975	22	37460	40	64278	58	84804	76	97029
	5	8715	23	39073	41	65605	59	85716	77	97437
	6	10452	24	40673	42	66913	60	86602	78	97814
	7	12186	25	42261	43	68199	61	87461	79	98162
	8	13917	26	43837	44	69465	62	88294	80	98480
	9	15643	27	45399	45	70710	63	89100	81	98768
	10	17364	28	46947	46	71933	64	89879	82	99026
	11	19080	29	48480	47	73135	65	90630	83	99254
	12	20791	30	50000	48	74314	66	91354	84	99452
	13	22495	31	51503	49	75470	67	92050	85	99619
	14	24192	32	52991	50	76604	68	92718	86	99756
	15	25881	33	54463	51	77714	69	93358	87	99862
	16	27563	34	55919	52	78801	70	93969	88	99939
	17	29237	35	57357	53	79863	71	94551	89	99984
	18	30901	36	58778	54	80901	72	95105	90	100000

THE Uſe of this Table will be obvious from two or three Examples. It was obſerved, (*Page* 26.) That the Power is to the Weight it ſuſtains on any inclined Plane IC, as the Height of the Plane IL to the Length thereof IC; that is, as the Sine of the Plane's Inclination to the Radius. Suppoſe the Angle of Inclination ICE = 40 Degrees, then will the Sine IL be equal to 64278, and the Radius CI equal to 100000, which Numbers are as 64 to 100; therefore 100 Pounds will be ſuſtain'd on the Inclined Plane by a Power equal to 64 Pounds nearly.

AGAIN; ſince EC = 100000 repreſents the *centrifugal Force* under the Equator, then will IM = 76604 (the Sine of 50 Degrees, and Co-Sine of 40) be as the ſaid Force in the Latitude of 40 Degrees: Which Numbers are as 1000 to 766; and ſuch is the Proportion of the Forces in thoſe two Places.

IN the ſame manner, if the Radius CD = 100000 expreſs the Force of any *direct Stroke*, then will the Sine IL = 64278 be expreſſive of the Force of an *oblique Stroke* in the Direction FC, every thing elſe being equal.

AGAIN; ſince the Force of a direct Stroke is expreſs'd by CD = 100000, if it be required to find the Angle of Obliquity, ſuch that the Force of the Stroke ſhall be but one fourth Part ſo great, or 25000, look in the Table for the Number neareſt to this, and you will perceive it lie between 14 and 15 Degrees, and therefore about 14 Degrees and a half is the Angle required.

IN the laſt Place: It was ſaid, (*Page* 29.) That *the Force of the Wind on the Sail is proportional to the Squares of the Sines of the Angle of Incidence.* This may be illuſtrated by Numbers, thus: If the Sail be turn'd to the ſame Wind, firſt under an Angle of 45 Degrees, and then under an Angle of 30 Degrees; the Sine of the firſt Angle is (by the *Table*) 70710, and of the latter 50000, the Squares of which are 4999904100 and 2500000000, which Squares are as 50 to 25, or as 2 to 1; and therefore the Power of the Wind is twice as great upon an Angle of 45 Degrees, as upon an Angle of 30.

BECAUSE the Square of the Sine of 45 Degrees is 5000000000, twice that Square will be 10000000000, which is equal to the Square of Radius 100000; 'tis evident the Sum of the Squares of the Sines of any two Angles above 45 Degrees will be greater than the Square of Radius; and therefore the Force of the Wind upon two oblique Sails, in that Caſe, will be greater than upon one Sail ſet direct before the Wind.

AFTER the ſame manner, the Table of Sines may be applied to Calculation in any other Caſe of like Nature, where the *Proportion of Radius and Sine of an Angle* is required to be expreſs'd or ſtated in Numbers. And ſince each Degree is divided into 60 equal Parts or *Minutes*, therefore the Sine of any Number of Degrees and Minutes alſo may be eaſily found by the foregoing Table, by thoſe who underſtand the Rule of Proportion.

Fig. XLVII. I SHALL only further obſerve here, that as I L is the *Sine*, and L M the *Co-Sine*, of the Arch I E; ſo if on the extreme Point E of the Radius C E we raiſe a Perpendicular which ſhall cut the Line C I, continued, in F, then is the ſaid Perpendicular E F call'd the TANGENT of the Angle I C E, and the Line F C the SECANT of the ſame Angle. In like manner, the Perpendicular D G is the *Tangent* of the Angle D C I, and G C the *Secant* thereof; and therefore D G is the *Co-Tangent*, and G C the *Co-Secant* of the Angle I C E. I thought it neceſſary to acquaint the Reader with theſe Definitions, becauſe they ſometimes occur in Treatiſes of this Kind.

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